

THE SPECIAL SENSES

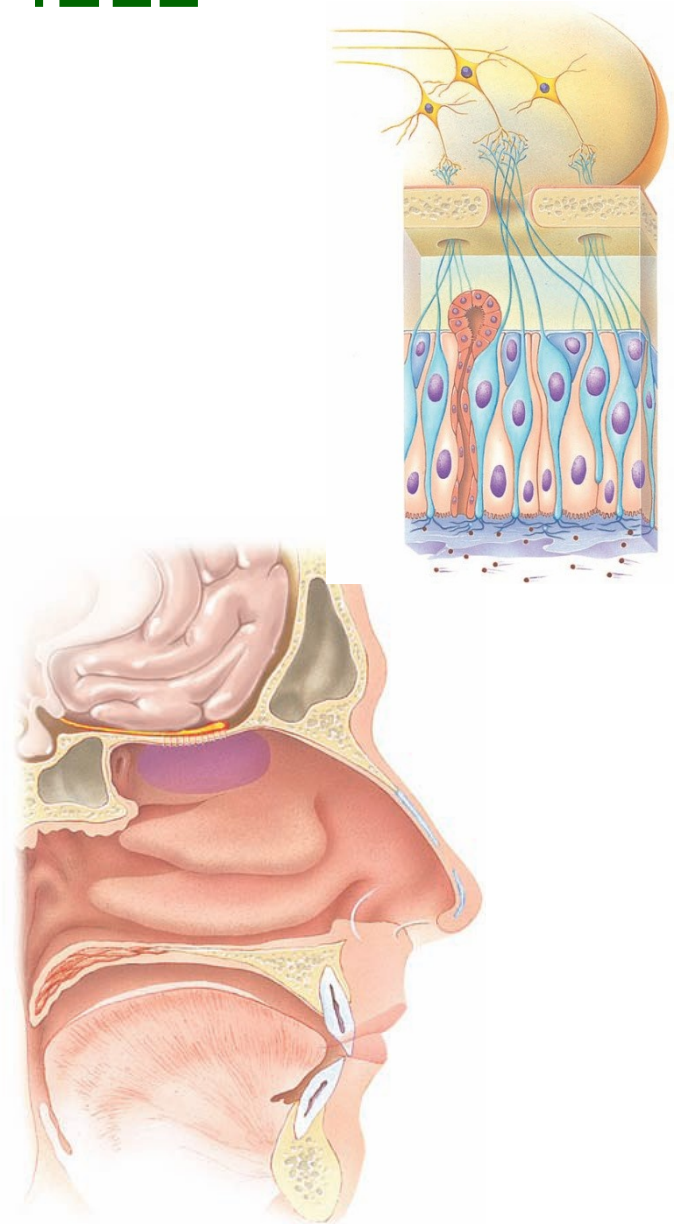
INTRODUCTION

Special Senses

- Recall that a sensation is the conscious or subconscious awareness of an internal or external stimulus
 - For this chapter, **“external stimulus”** means **light rays** striking the retina of the eye, **sound waves** impinging on the tympanic membrane of the ear, **molecules in the air and food** transmitting smells and tastes to the chemical sensors in the nose and on the tongue, and the force of gravity acting on equilibrium receptors in the inner ear which sense changes in inertia

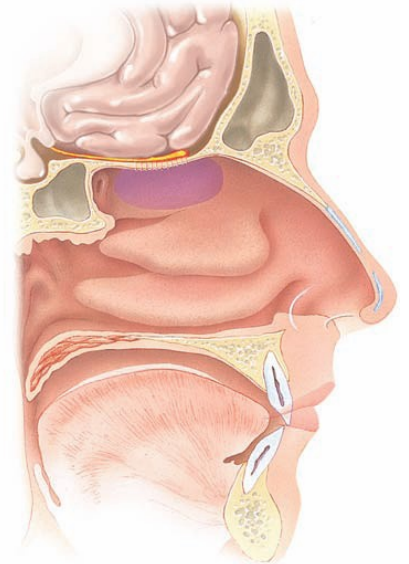
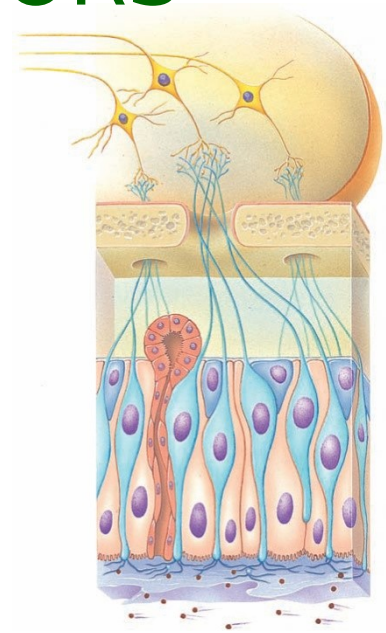
OLFACTION: SENSE OF SMELL

- chemical sensation
- sensation arises from the interaction of molecule with smell receptors.



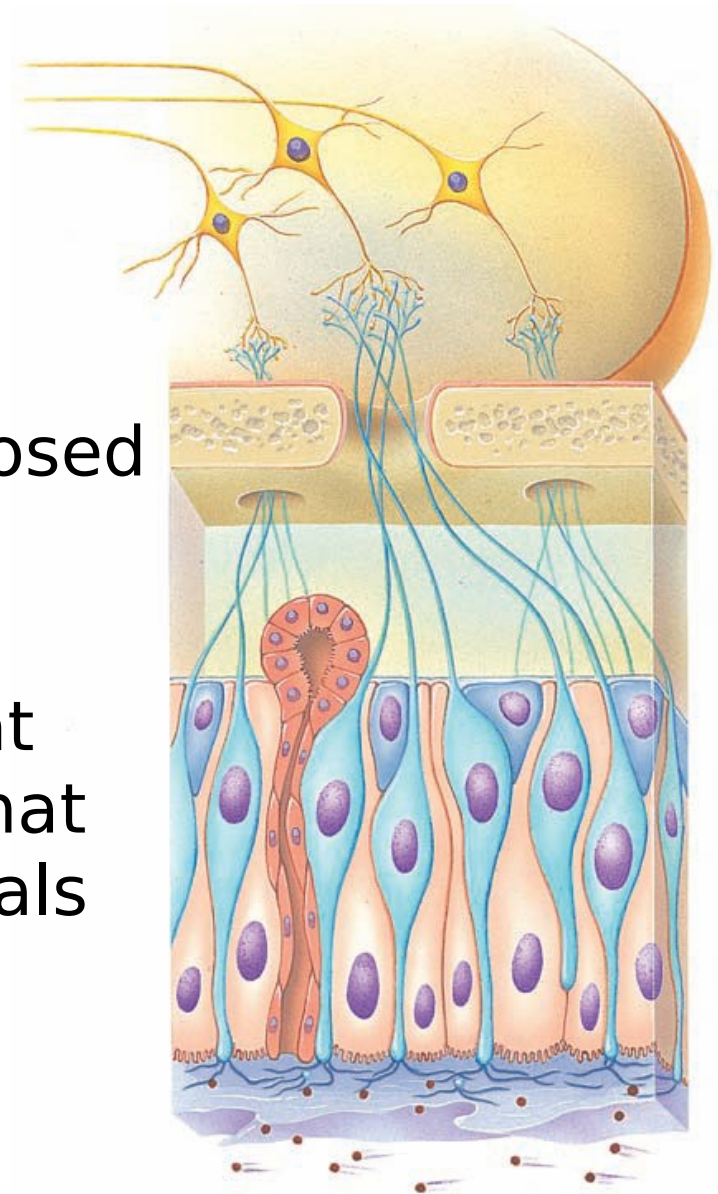
ANATOMY OF OLFACTORY RECEPTORS

- Human can recognize about 10,000 different odors
- Human nose contains 10 million to 100 million smell receptors located in OLFACTORY EPITHELIUM
 - occupies the superior part of the nasal cavity
 - covers the inferior surface of the cribriform plate
 - extends along the superior nasal concha



CELLS OF THE OLFACTORY EPITHELIUM

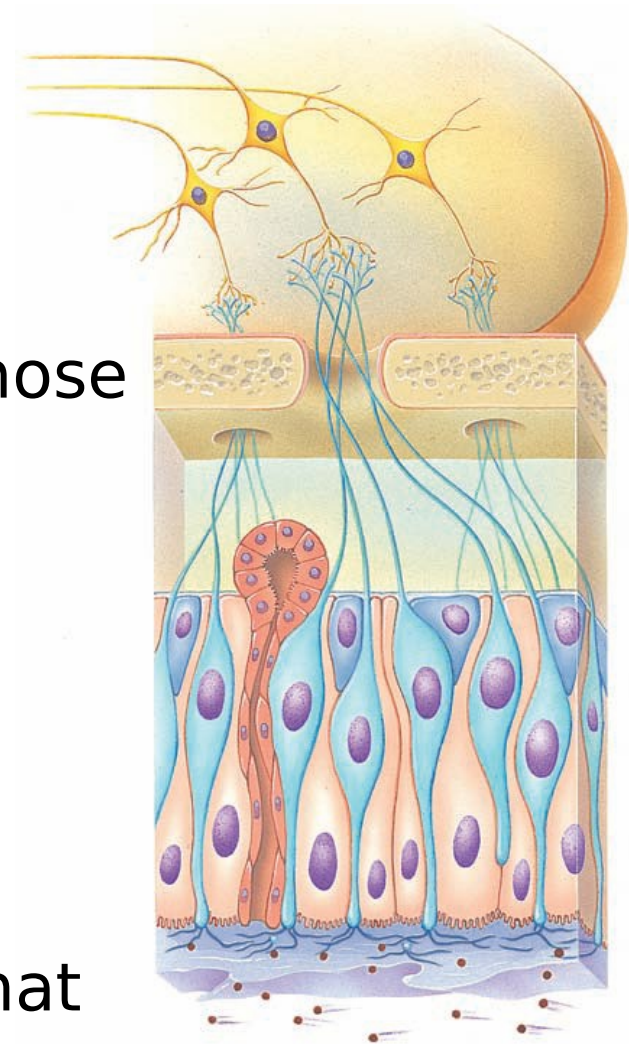
- **OLFACTORY RECEPTORS**
 - bipolar neuron with an exposed knob-shaped dendrite
 - **OLFACTORY HAIRS**, cilia that project from the dendrite that respond to inhaled chemicals



CELLS OF THE OLFACTORY EPITHELIUM

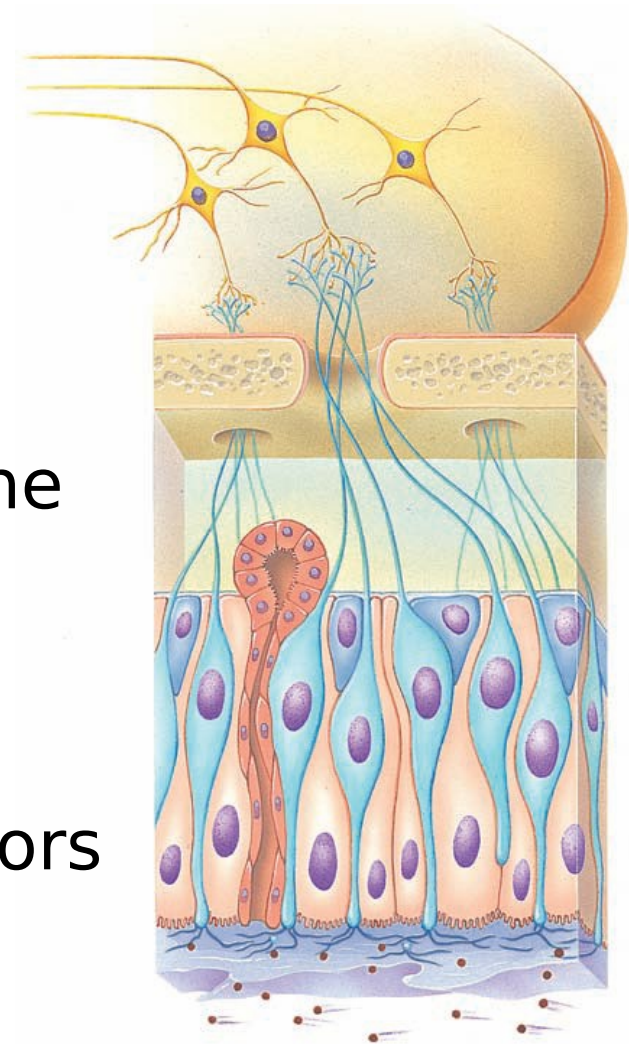
- SUPPORTING CELLS

- columnar epithelial cells of the mucous membrane lining the nose
- they provide physical support, nourishment, and electrical insulation for the olfactory receptors.
- they help detoxify chemicals that come in contact with the olfactory epithelium.



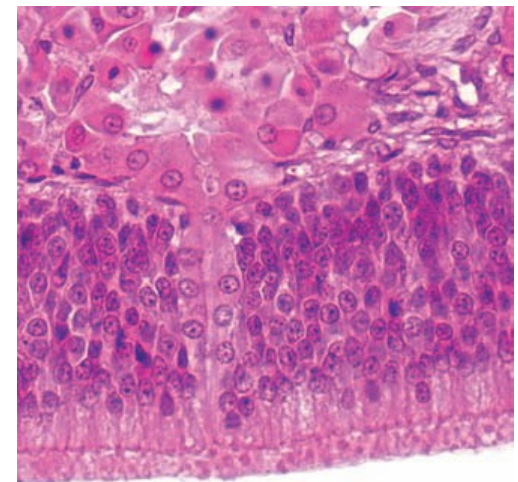
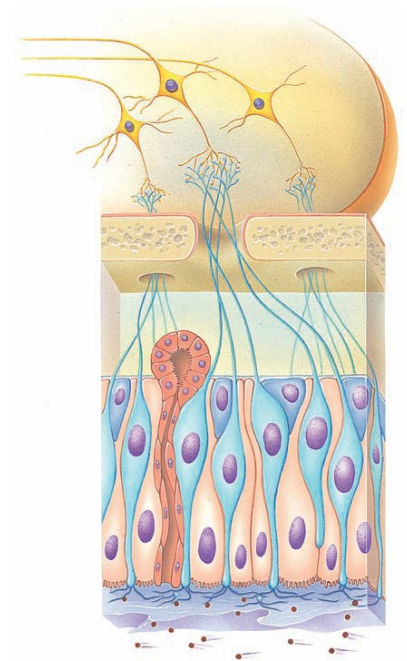
CELLS OF THE OLFACTORY EPITHELIUM

- **BASAL CELL**
 - stem cells located between the bases of the supporting cells
 - they undergo cell division to produce new olfactory receptors



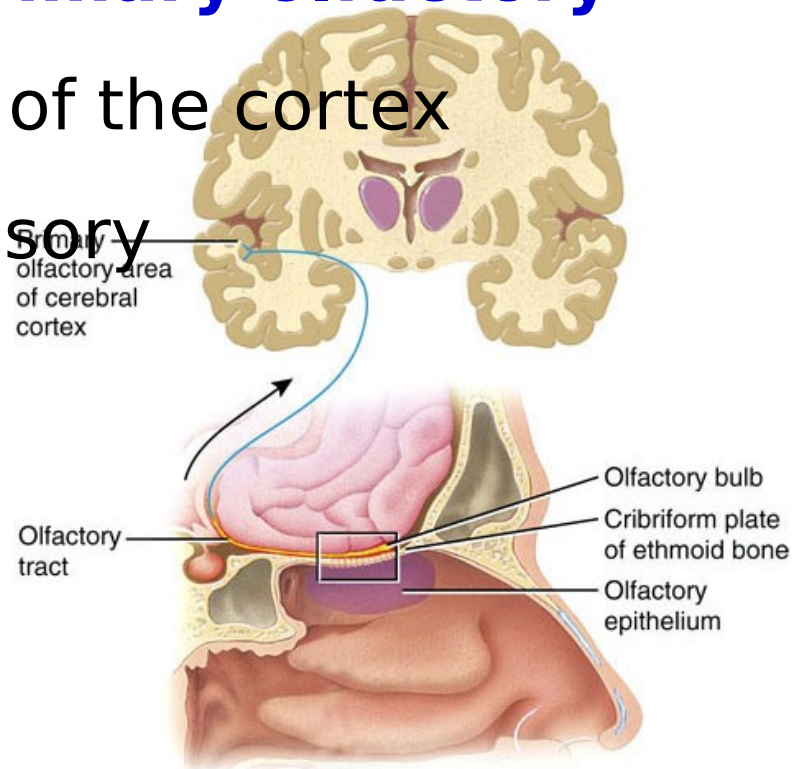
CELLS OF THE OLFACTORY EPITHELIUM

- OLFACTORY (BOWMAN'S) GLAND
 - produce mucus that moistens the surface of the olfactory epithelium and dissolves odorants so that transduction can occur
 - Innervated by autonomic neurons within branches of the facial (VII) nerve

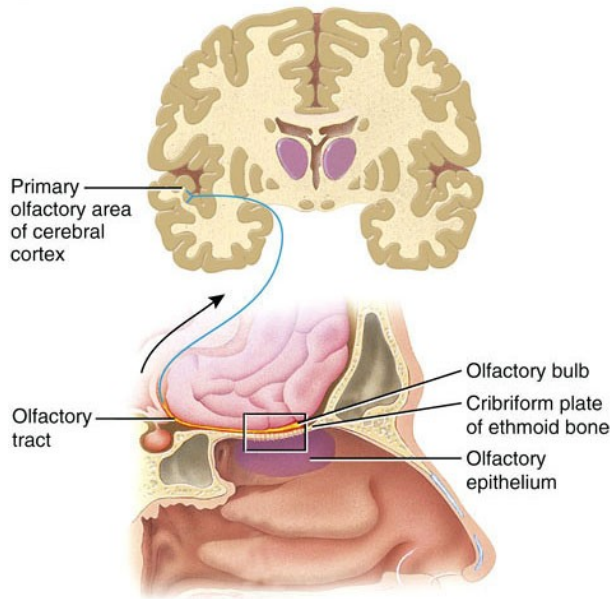


OLFACTION PHYSIOLOGY

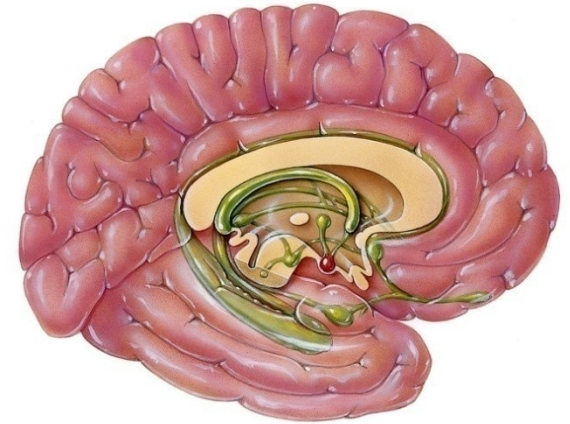
- Once generated, nerve impulses travel through the two olfactory nerves → olfactory bulbs → olfactory tract → **primary olfactory area** in the temporal lobe of the cortex
- Olfaction is the only sensory system that has direct cortical projections without first going through relay stations



OLFACTORY PATHWAY



OLFACTORY NERVE ↓
OLFACTORY BULB ↓
OLFACTORY TRACT ↓
OLFACTORY NERVE



PRIMARY OLFACTORY AREA

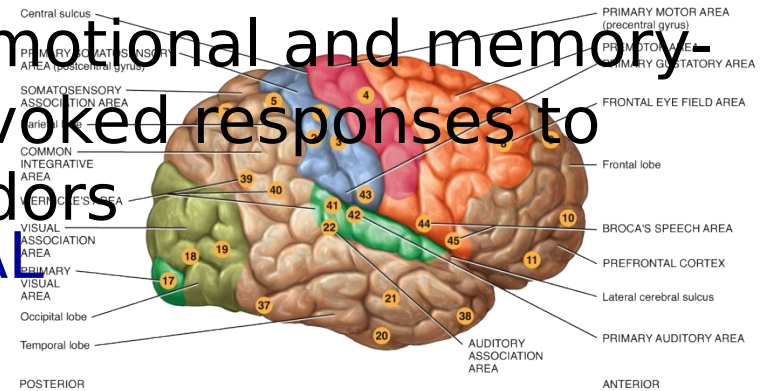
Temporal Lobe of the Cortex
Conscious awareness of smell begins

**LIMBIC SYSTEM/
HYPOTHALAMUS**

Emotional and memory-evoked responses to odors

ORBITOFRONTAL AREA (FRONTAL LOBE)

odor identification and



GUSTATION

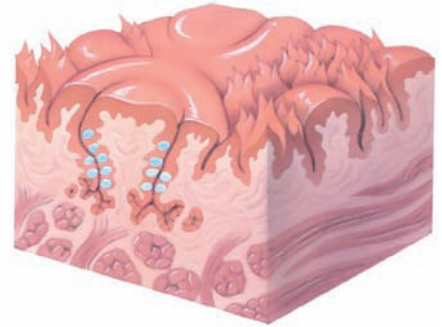
GUSTATION: SENSE OF TASTE

- chemical sensation
- only five primary tastes can be distinguished
 - SOUR
 - SWEET
 - BITTER
 - SALTY
 - UMAMI (meaty/savory)
- less sensitive than olfaction



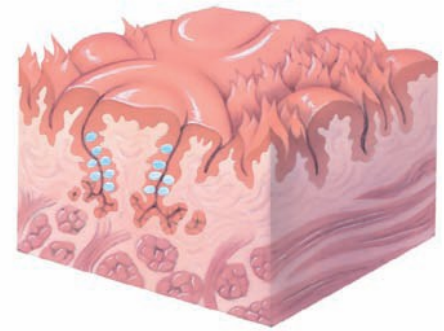
ANATOMY OF TASTE BUDS and PAPILLAE

- approx. 10,000 taste buds are located at the tongue
- SOFT PALATE
- EPIGLOTTIS
- PHARYNX
- the number of taste buds declines with age



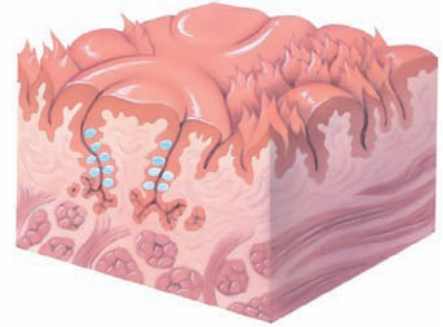
ANATOMY OF TASTE BUDS

- **SUPPORTING CELLS**
 - surrounds 50 gustatory cells
- **BASAL CELLS**
 - stem cells found that develop into supporting cells and then into gustatory receptor cells
- **GUSTATORY RECEPTOR CELLS**
 - main cell types for the sense of taste
 - 10 days life span



ANATOMY OF PAPILLAE

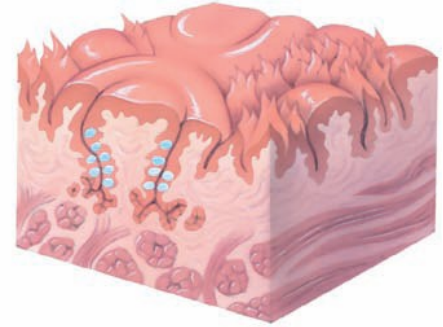
- elevations which increase the surface area and provide a rough texture to the upper surface of the tongue
- **VALLATE (CIRCUMVALLATE) PAPILLAE**
 - about 12 very large circular elevations that form an inverted V-shaped row at the back of the tongue
 - each of these papillae houses 100–300 taste buds.



ANATOMY OF PAPILLAE

- **FUNGIFORM PAPILLAE**

- mushroom-shaped elevations scattered over the entire surface of the tongue that contain about five taste buds each.



- **FOLIATE PAPILLAE**

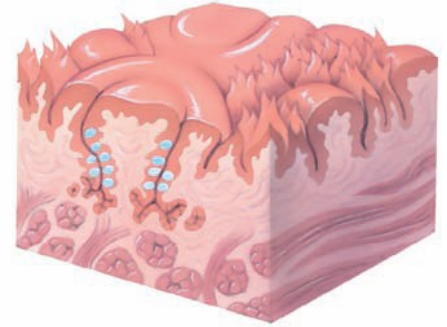
- leaf-like elevations located in small trenches on the lateral margins of the tongue.
- most of their taste buds degenerate in early childhood



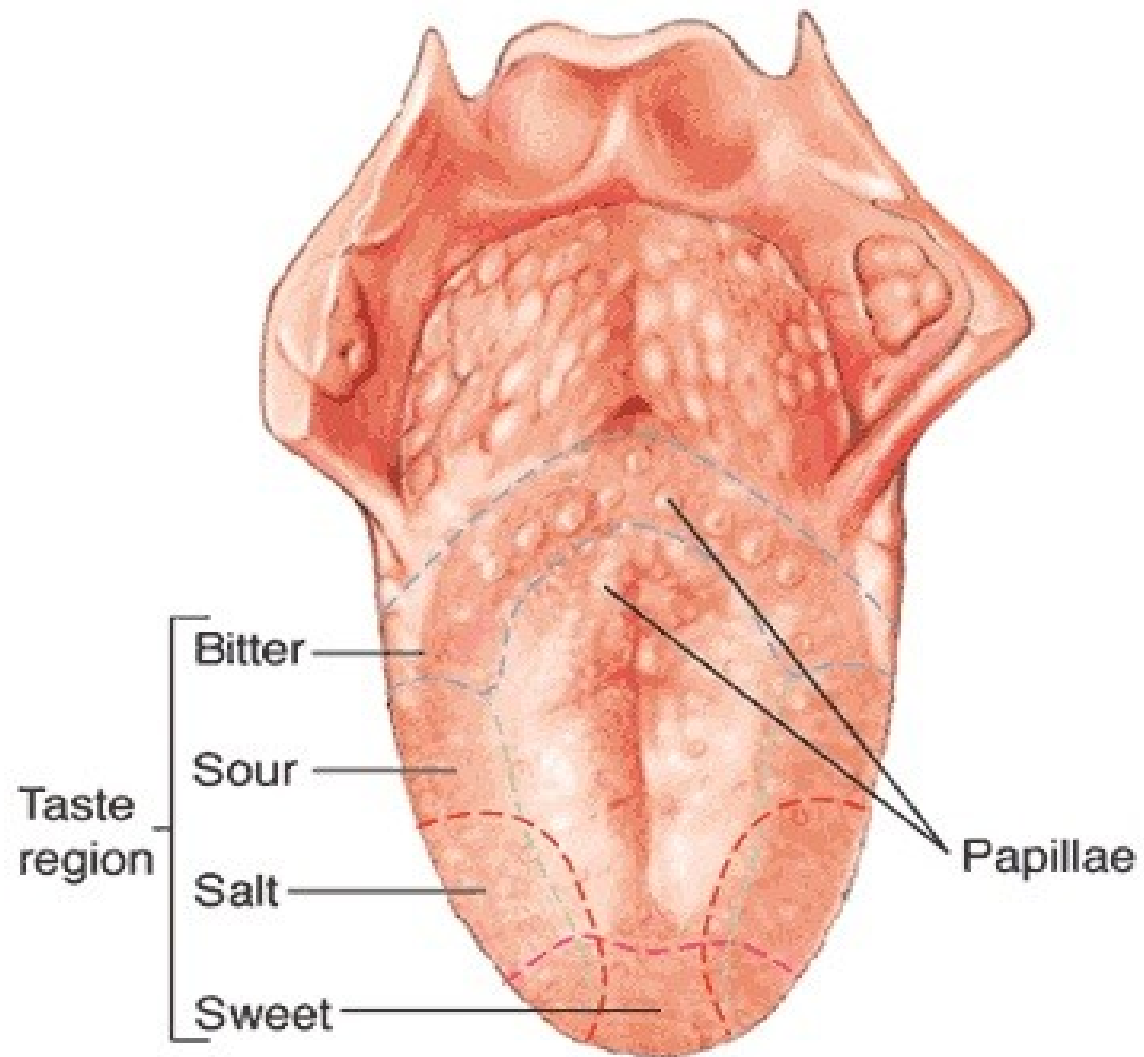
ANATOMY OF PAPILLAE

- **FILIFORM PAPILLAE**

- pointed, threadlike structures contain tactile receptors but no taste buds
- they increase friction between the tongue and food, making it easier for the tongue to move food in the oral cavity

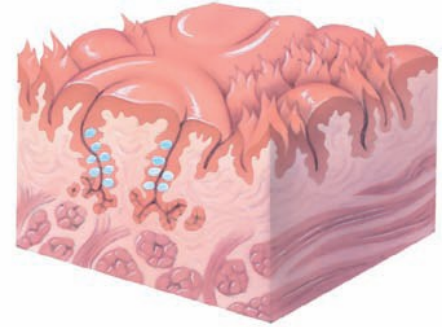


GUSTATION



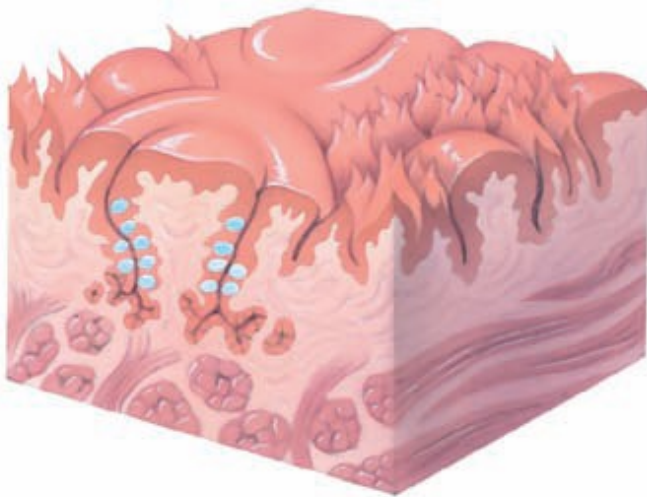
TASTE THRESHOLDS

- threshold for taste varies for each of the primary tastes
- The threshold for **BITTER** substances is the lowest.
- The threshold for **SOUR** substances is somewhat higher
- The thresholds for **SALTY** substances and for **SWEET** substances are higher than those for bitter or sour substances.

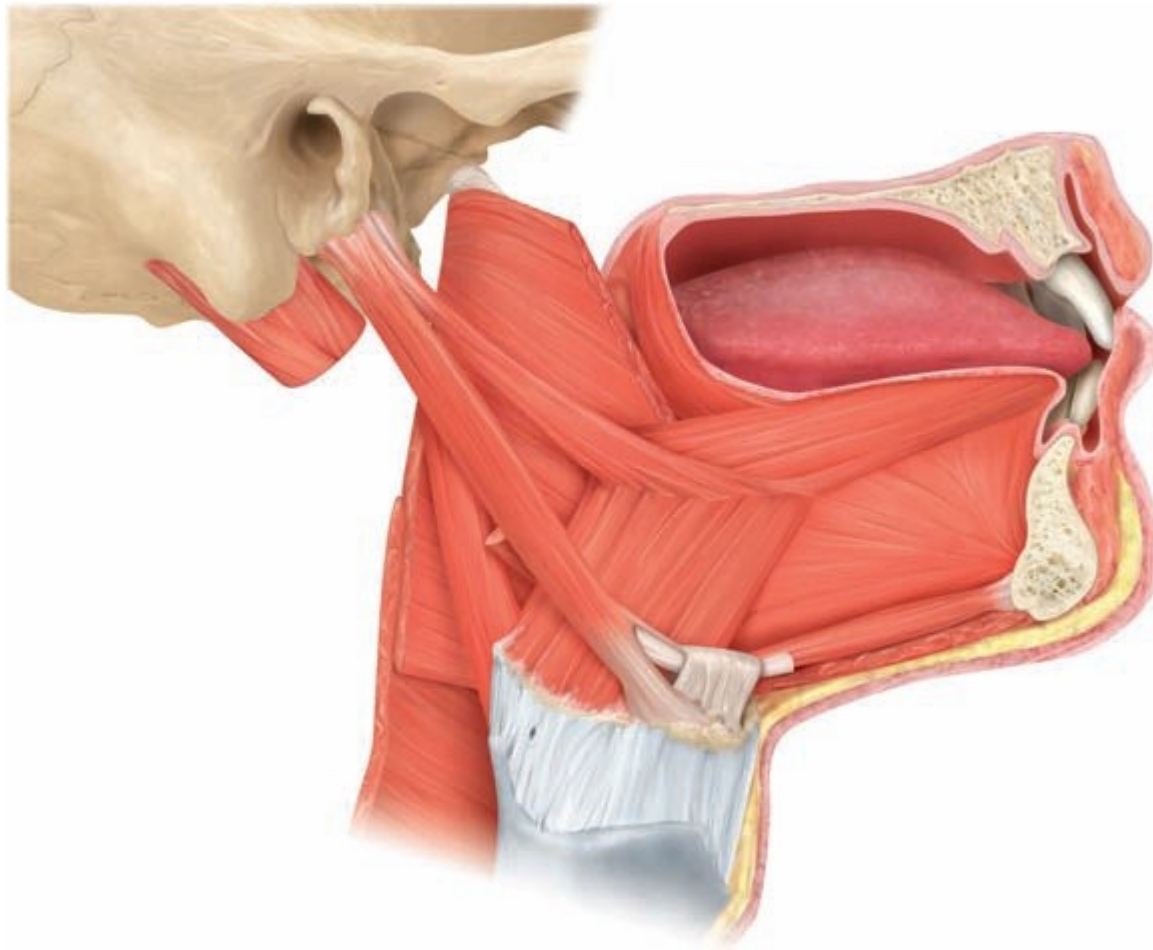


TASTE ADAPTATIONS

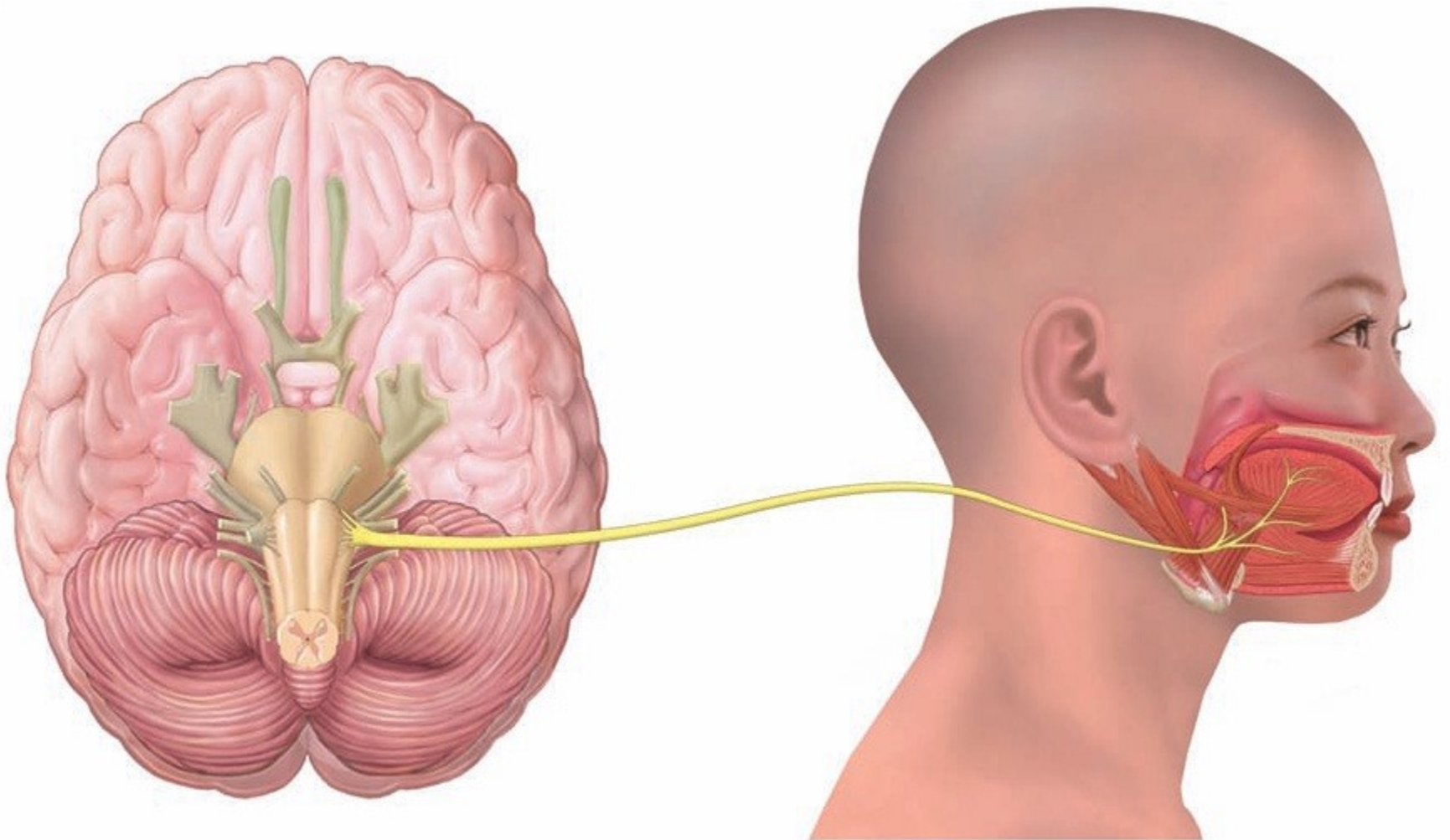
- complete adaptation to a specific taste can occur in 1-5 minutes of continuous stimulation



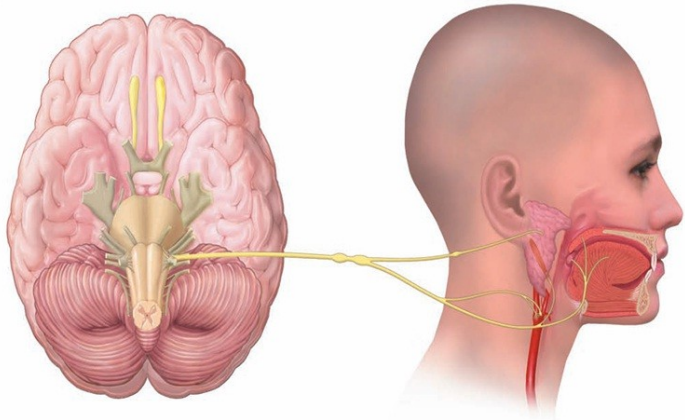
MUSCLES THAT MOVE THE TONGUE AND ASSIST IN MASTICATION



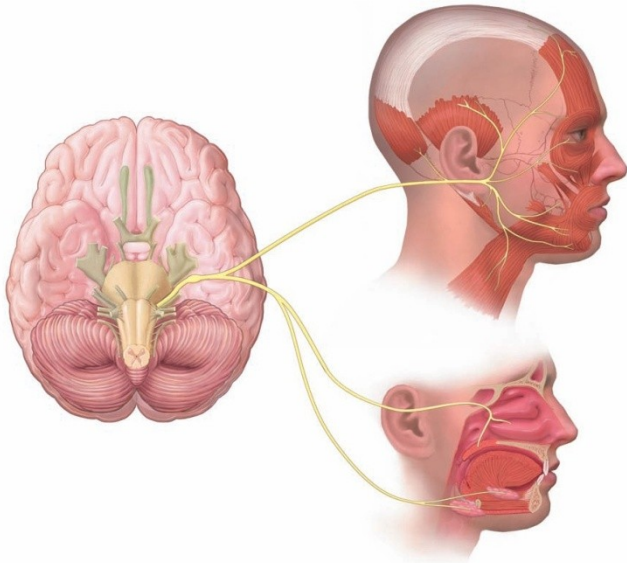
INNERVATION



gustation: SENSORY NERVES

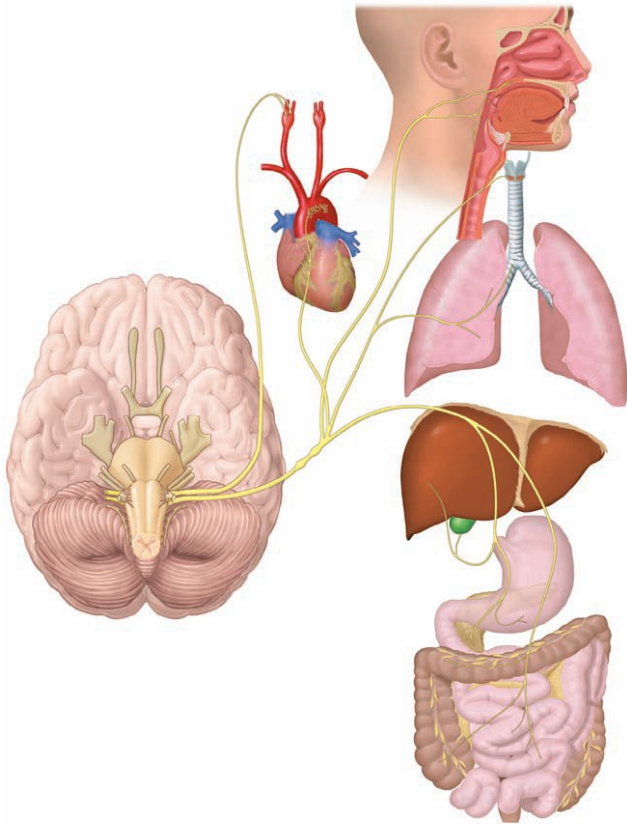


- glossopharyngeal nerve
- serves taste buds in the posterior one-third of the tongue



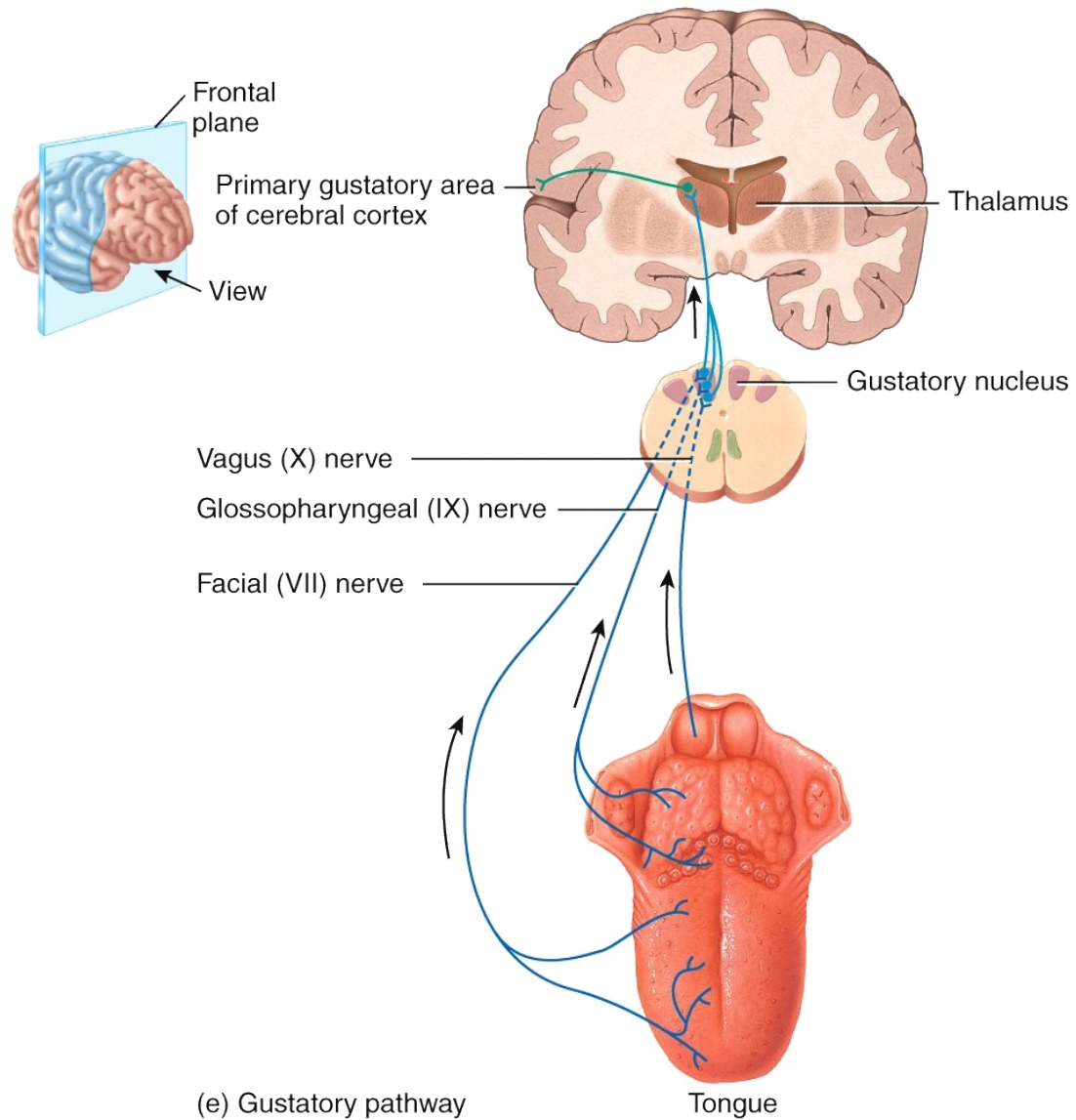
- facial nerve
- serves taste buds in the anterior two-thirds of the tongue

gustation: SENSORY NERVE



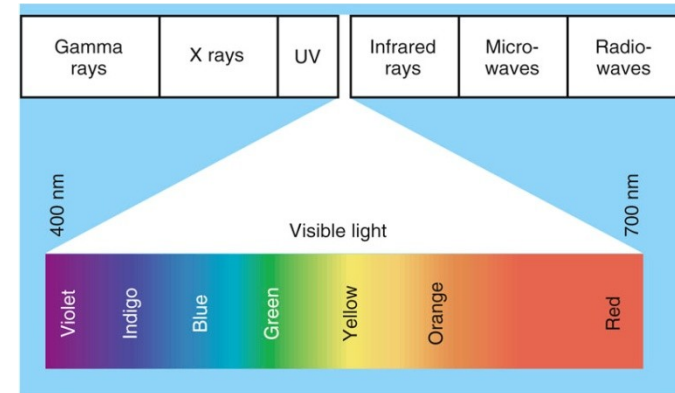
- vagus nerve
- serves taste buds in the throat and epiglottis

GUSTATORY PATHWAY

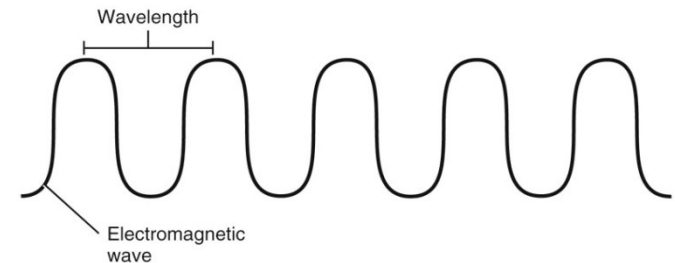


VISION

- the act of seeing and is extremely important to human survival.
- More than half the sensory receptors in the human body are located in the eyes.
- A large part of the cerebral cortex is devoted to processing visual information
- The eyes are responsible for the detection of visible light, the part of the electromagnetic spectrum with wavelengths ranging from about 400 to 700 nm. Visible light exhibits colors



(a) Electromagnetic spectrum

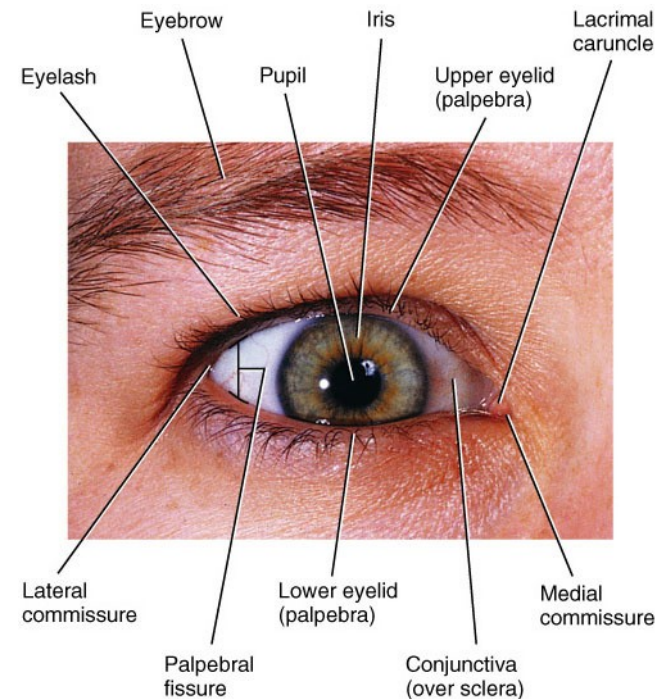


(b) An electromagnetic wave

ACCESSORY STRUCTURE OF THE EYE

- EYELIDS (PALPABRAE)

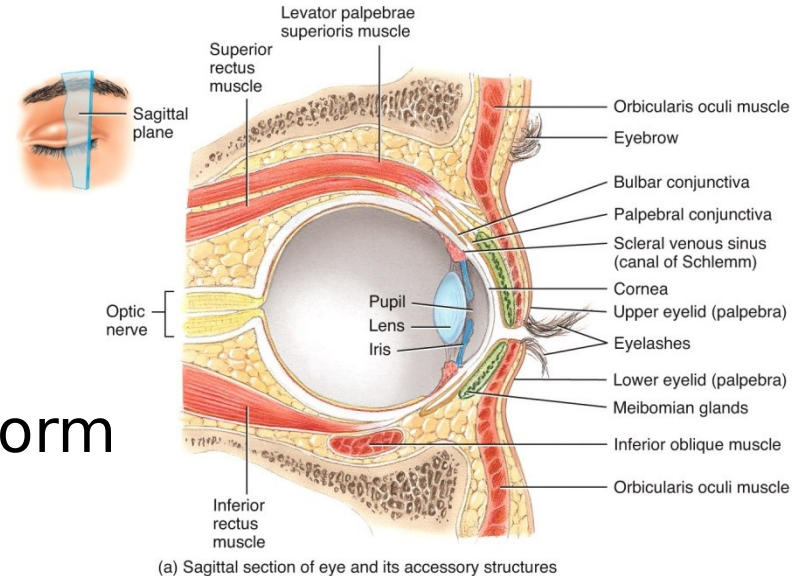
- shade the eyes during sleep
- protect the eyes from excessive light and foreign objects
- spread lubricating secretions over the eyeballs



ACCESSORY STRUCTURE OF THE EYE

- **EYELIDS (PALPABRAE)**

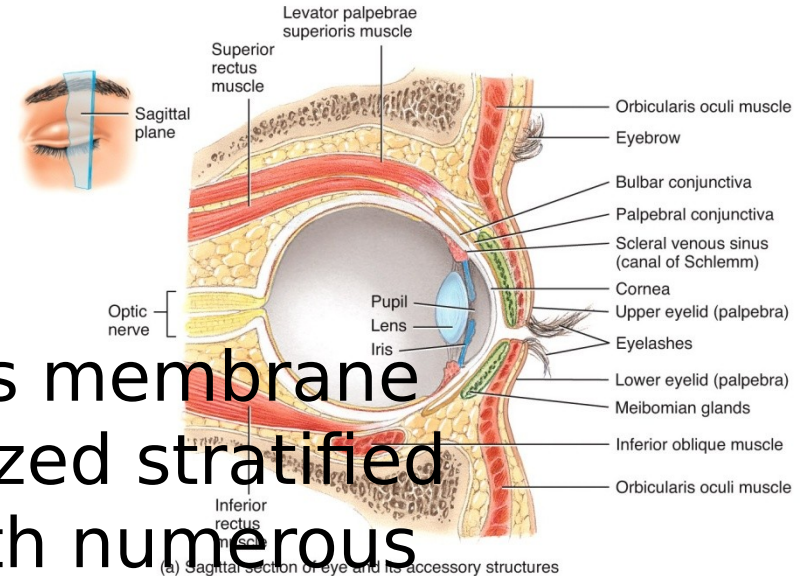
- **tarsal plate**, a thick fold of connective tissue that gives form and support to the eyelids
 - **tarsal or Meibomian glands**, secrete a fluid that helps keep the eyelids from adhering to each other
 - **CHALAZION**, tumor or cyst formed due to infection of the tarsal glands
- p



ACCESSORY STRUCTURE OF THE EYE

- **CONJUNCTIVA**

- a thin, protective mucous membrane composed of nonkeratinized stratified squamous epithelium with numerous goblet cells that is supported by areolar connective tissue.



- **PALPEBRAL CONJUNCTIVA**, lines the inner aspect of the eyelids
- **BULBAR CONJUNCTIVA**, passes from the eyelids onto the surface of the eyeball

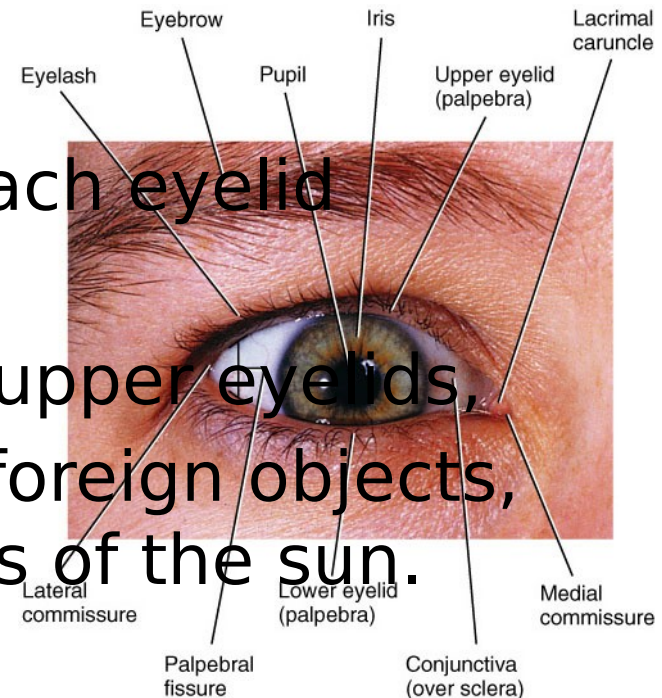
ACCESSORY STRUCTURE OF THE EYE

- **EYELASHES**

- project from the border of each eyelid

- **EYEBROWS**

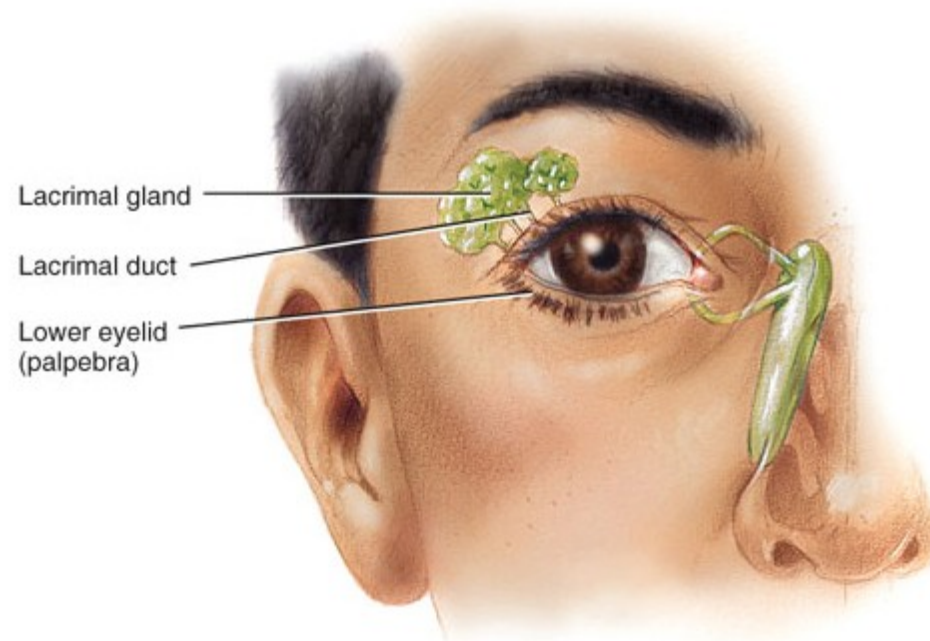
- arch transversely above the upper eyelids,
 - help protect the eyeballs from foreign objects, perspiration, and the direct rays of the sun.



- **SEBACEOUS CILIARY GLANDS** , sebaceous glands at the base of the hair follicles of the eyelashes that release a lubricating fluid into the follicles.
 - **STY**, pus-filled swelling of sebaceous ciliary glands due to bacteria infection

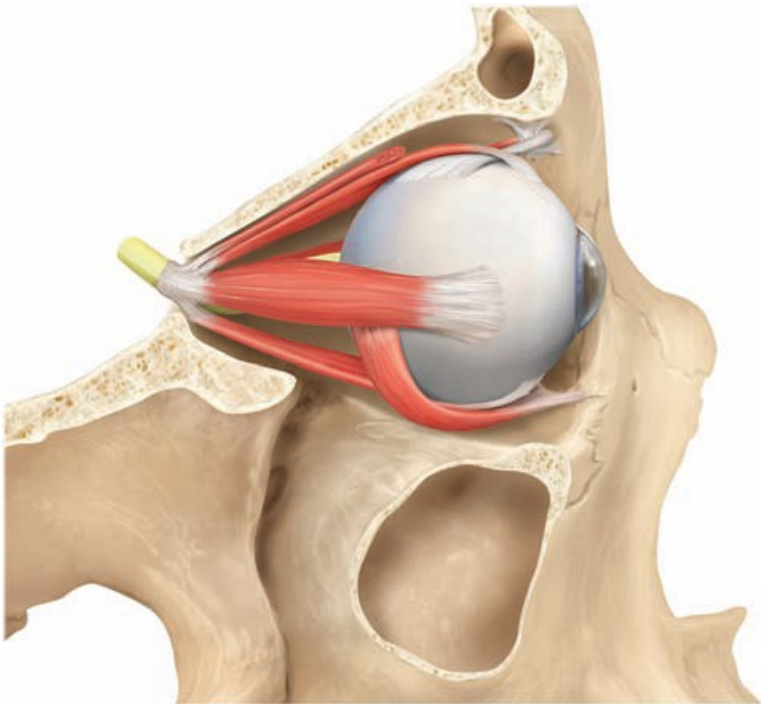
ACCESSORY STRUCTURE OF THE EYE

- LACRIMAL APPARATUS



ACCESSORY STRUCTURE OF THE EYE

- EXTRINSIC MUSCLES OF THE EYE



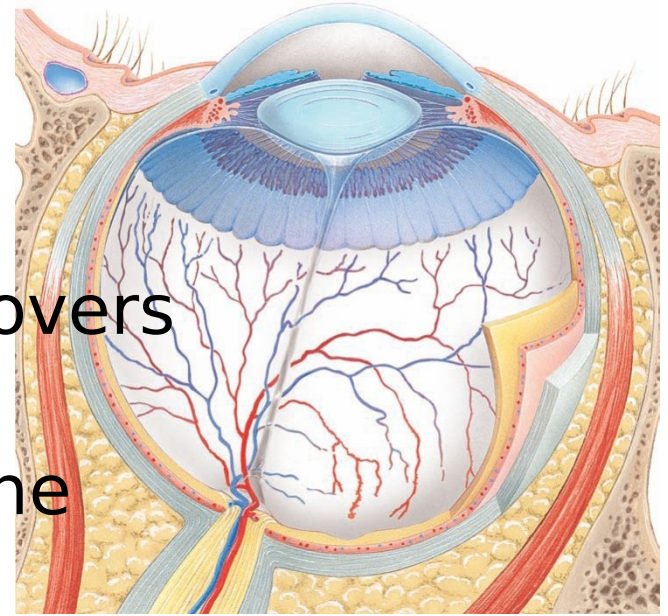
EYEBALL

ANATOMY OF THE EYEBALL

- FIBROUS TUNIC

- CORNEA

- a transparent coat that covers the colored iris
 - it helps focus light onto the retina



- SCLERA

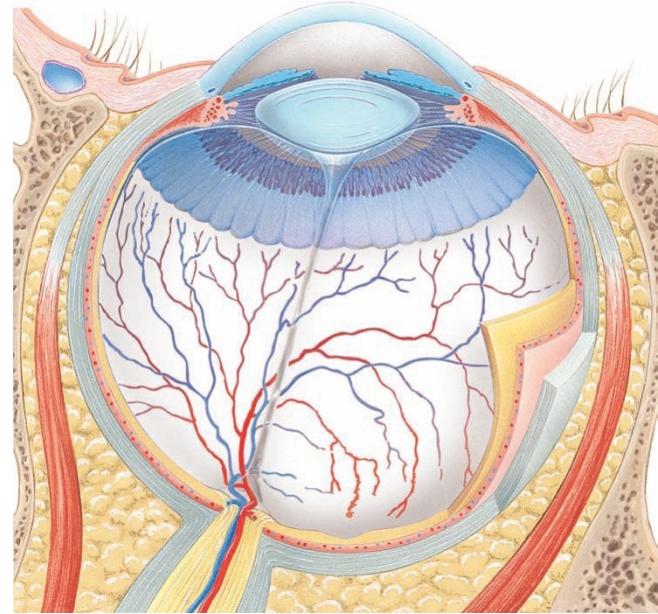
- covers and gives shape to the eyeball, makes it more rigid, protects its inner parts
 - serves as a site of attachment for the extrinsic eye muscles

ANATOMY OF THE EYEBALL

- VASCULAR TUNIC/ UVEA

- CHOROID

- highly vascularized thus provide nutrients to the posterior surface of the retina
- contains melanocytes that absorb stray light rays thus, prevents reflection and scattering of light

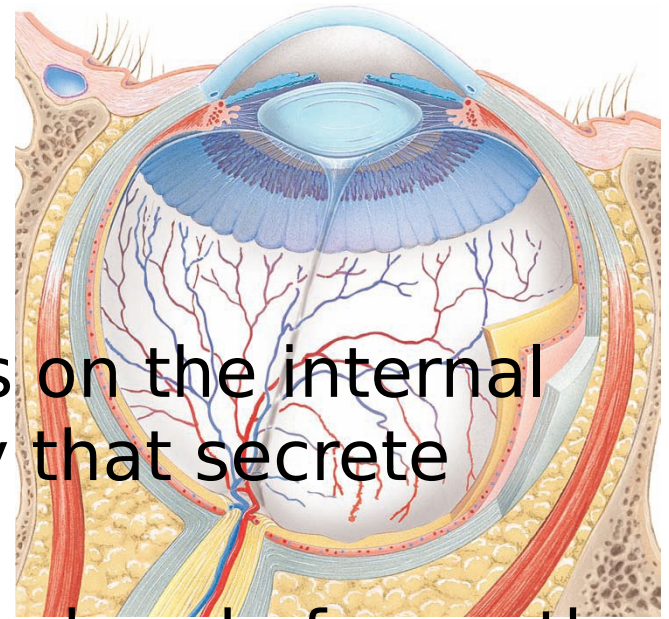


ANATOMY OF THE EYEBALL

- VASCULAR TUNIC/ UVEA

- CILIARY BODY

- **CILIARY PROCESSES**, folds on the internal surface of the ciliary body that secrete aqueous humor
- **CILIARY MUSCLE**, a circular band of smooth muscle
- **ZONULAR (SUSPENSORY LIGAMENTS) FIBERS**, extending from the ciliary processes that resemble elastic connective tissue fibers



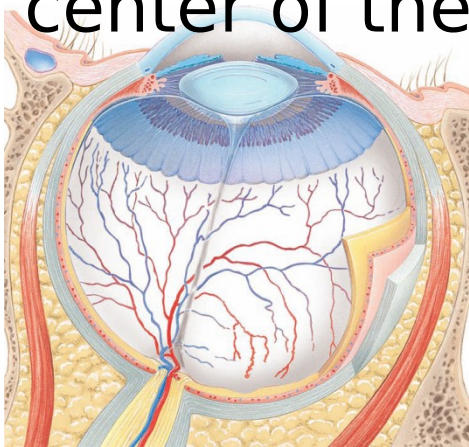
- Contraction or relaxation of the ciliary muscle changes the tightness of the zonular fibers

ANATOMY OF THE EYEBALL

- VASCULAR TUNIC/ UVEA

- IRIS

- the colored portion of the eyeball and shaped like a flattened donut
- it is consist of melanocytes and circular and radial smooth muscle fibers
- it regulates the amount light entering the eyeball through the **PUPIL**, the hole in the center of the iris

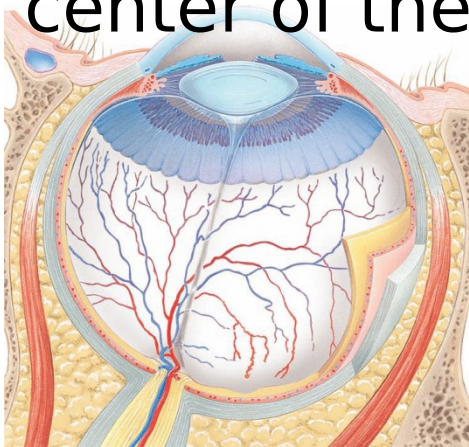


ANATOMY OF THE EYEBALL

- VASCULAR TUNIC/ UVEA

- IRIS

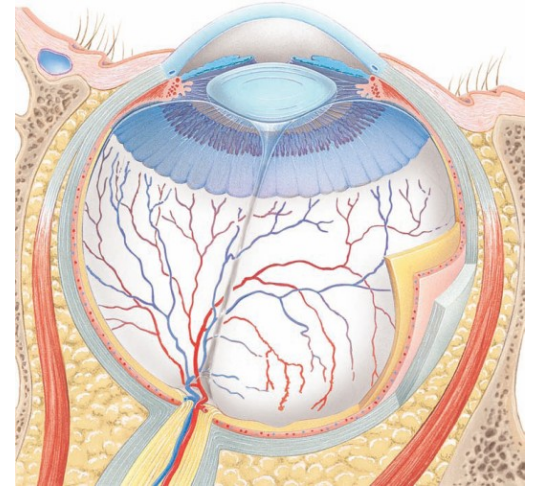
- the colored portion of the eyeball and shaped like a flattened donut
- it is consist of melanocytes and circular and radial smooth muscle fibers
- it regulates the amount light entering the eyeball through the **PUPIL**, the hole in the center of the iris



ANATOMY OF THE EYEBALL

- RETINA

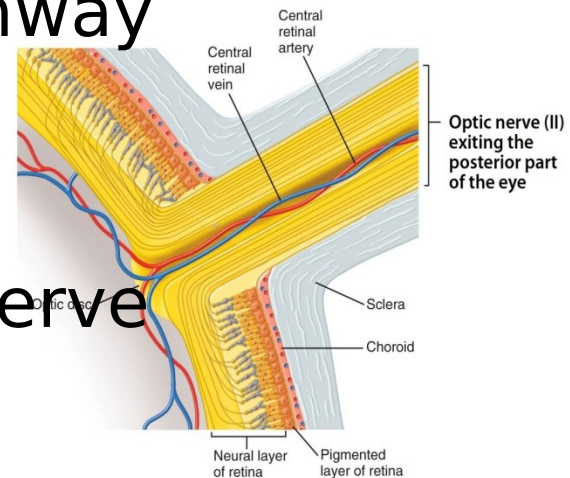
- the third and inner layer of the eyeball



- the beginning of the visual pathway

- OPTIC DISC

- the site where the optic (II) nerve exits the eyeball



- **BLIND SPOT** (it contains no rods or cones, we cannot see images that

X



ANATOMY OF THE EYEBALL

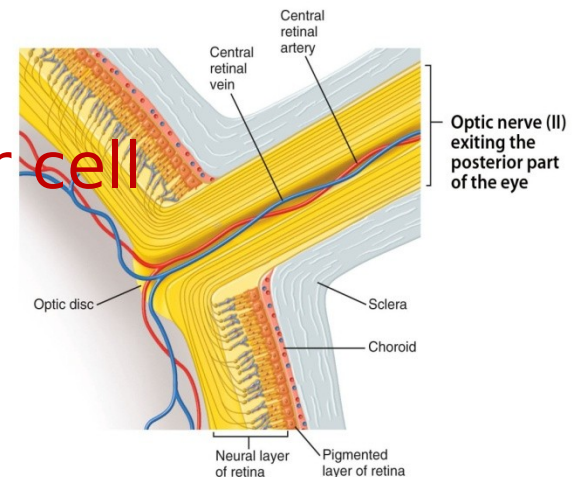
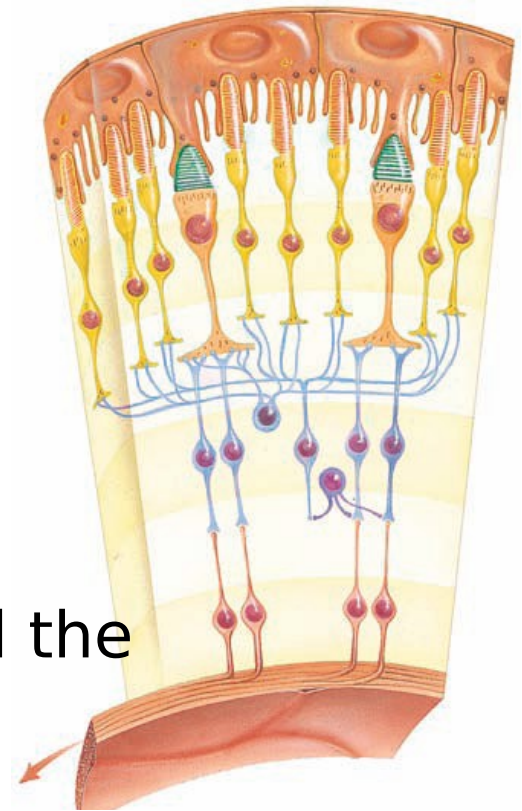
- RETINA

- PIGMENTED LAYER

- a sheet of melanin-containing epithelial cells
- located between the choroid and the neural part of the retina

- NEURAL LAYER

- photoreceptor layer, the bipolar cell layer,
and the ganglion cell layer



ANATOMY OF THE EYEBALL

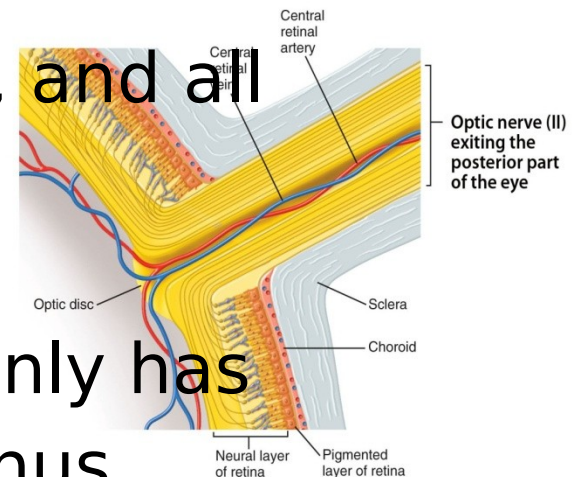
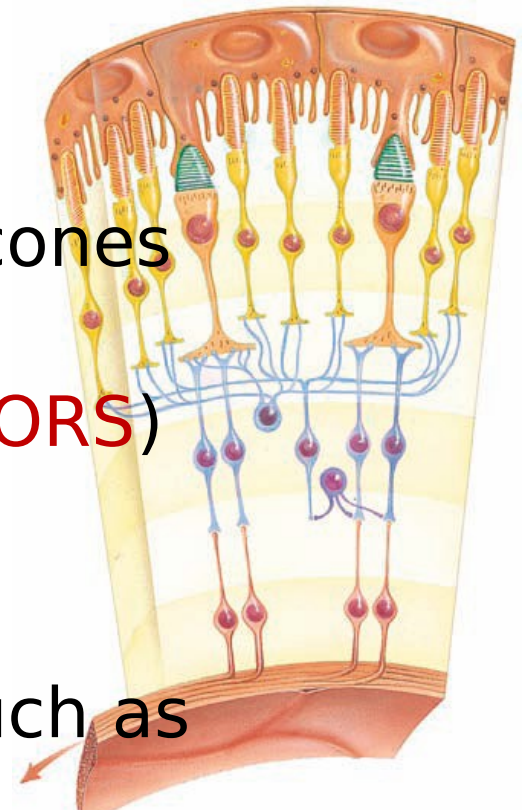
- RETINA

- each retina has about 6 million cones and 120 million rods (**PHOTORECEPTORS**)

- RODS

- allow us to see in dim light, such as moonlight
- we can see only black, white, and all shades of gray in between.

- A person who loses rod vision mainly has difficulty seeing in dim light and thus



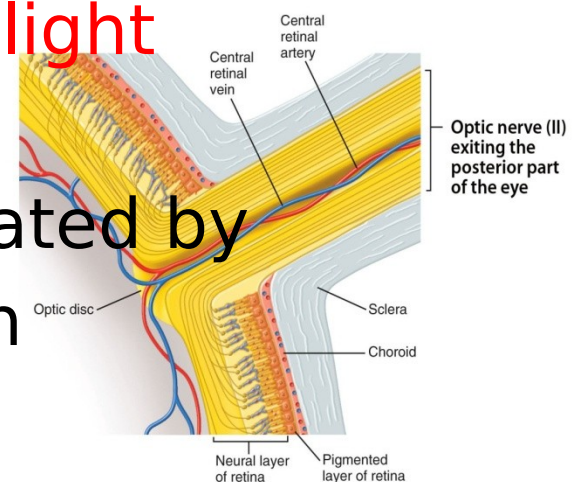
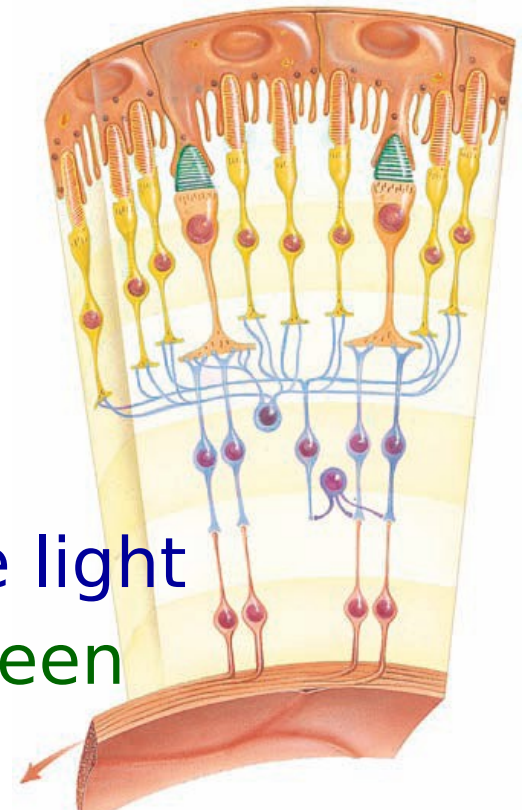
ANATOMY OF THE EYEBALL

- RETINA

- CONES

- produce color vision
- BLUE CONES, sensitive to blue light
- GREEN CONES, sensitive to green light
- RED CONES, sensitive to red light

- Most of our experiences are mediated by the cone system, the loss of which produces legal blindness.

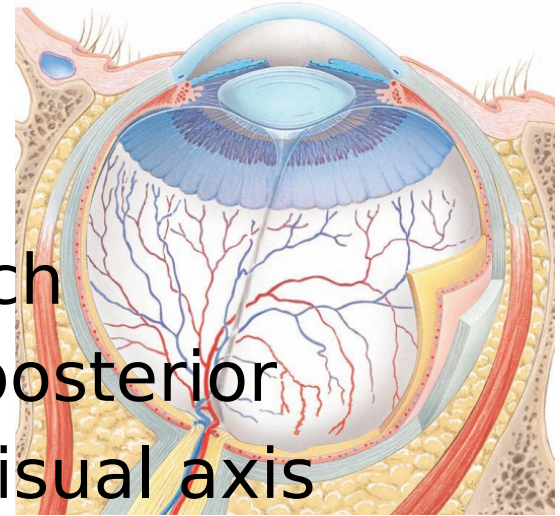


ANATOMY OF THE EYEBALL

- RETINA

- MACULA LUTEA

- yellowish, small flat spot which is in the exact center of the posterior portion of the retina, at the visual axis of the eye



- FOVEA CENTRALIS

- a small depression in the center of the macula lutea that contains only cones.
 - it is the area of highest **VISUAL ACUITY** or **RESOLUTION** (sharpness of vision)

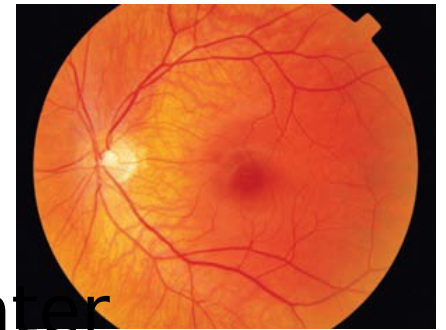


IMAGE FORMATION

1. **REFRACTION** or bending of light by the lens and cornea
2. **ACCOMODATION**, the change in shape of the lens
3. **CONSTRICTION** or narrowing of the

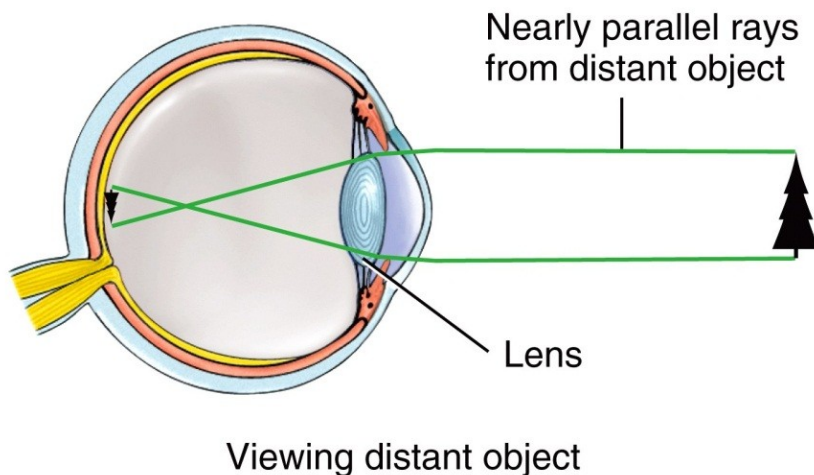
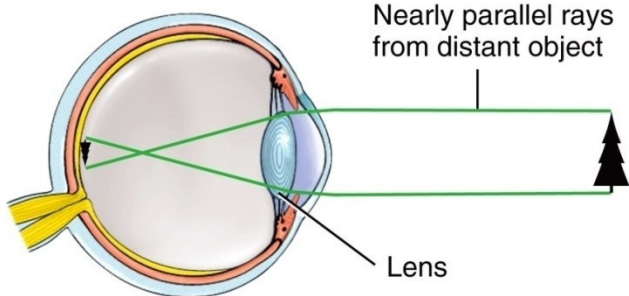


IMAGE FORMATION

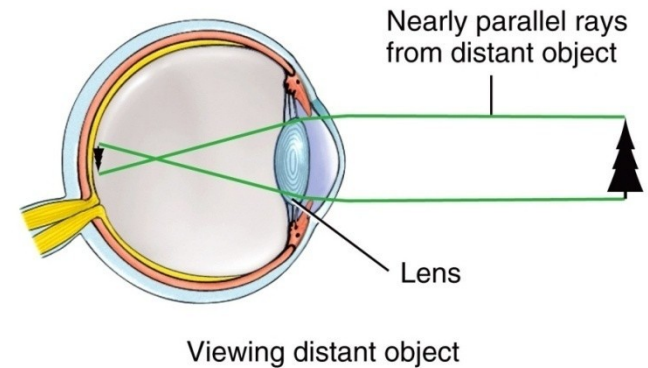
1. REFRACTION or bending of light by the lens and cornea

- as light rays enter the eye, they are refracted at the anterior and posterior surfaces of the cornea.
- both surfaces of the lens of the eye further refract the light rays so they come focus on the retina.



Viewing distant object

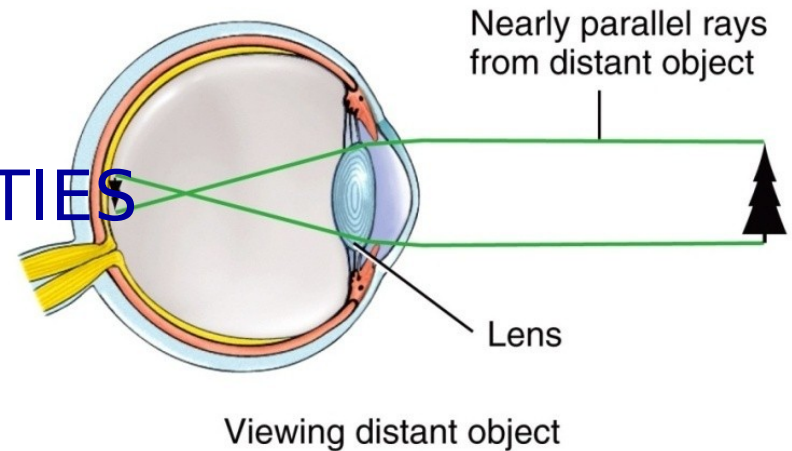
IMAGE FORMATION



1. **REFRACTION** or bending of light by the lens and cornea
 - about 75% of the total refraction of light occurs at the cornea.
 - the lens provides the remaining 25% of focusing power and also changes the focus to view near or distant objects.
 - when an object is 6 m (20 ft) or more away from the viewer, the light rays reflected from the object are nearly parallel to one

IMAGE FORMATION

- REFRACTION ABNORMALITIES

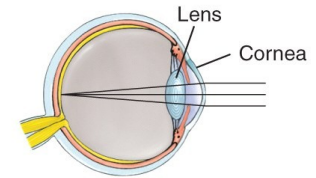


- PRESBYOPIA

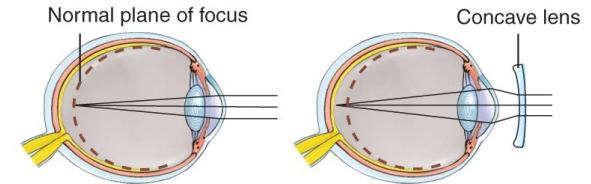
- With aging, the lens loses elasticity and thus its ability to curve to focus on objects that are close
- By age 40 the near point of vision may have increased to 20 cm (8 in.), and at age 60 it may be as much as 80 cm (31 in.).

IMAGE FORMATION

- REFRACTION ABNORMALITIES
(SIZE OF THE EYEBALL)



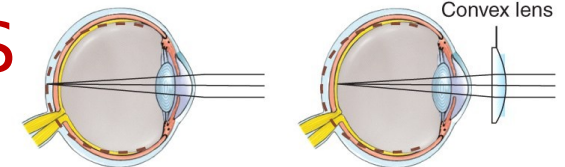
(a) Normal (emmetropic) eye



(b) Nearsighted (myopic) eye, uncorrected

(c) Nearsighted (myopic) eye, corrected

- MYOPIA or NEARSIGHTEDNESS



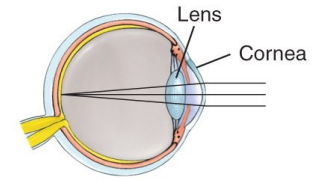
(d) Farsighted (hyperopic) eye, uncorrected

(e) Farsighted (hyperopic) eye, corrected

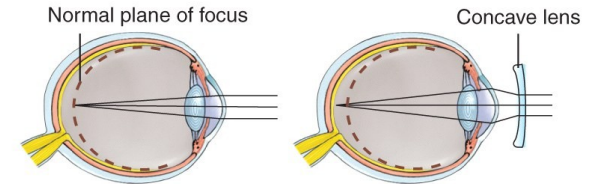
- the eyeball is too long relative to the focusing power of the cornea and lens
- the lens is thicker than normal
- RESULT:** an image converges in front of the retina

IMAGE FORMATION

- REFRACTION ABNORMALITIES
(SIZE OF THE EYEBALL)

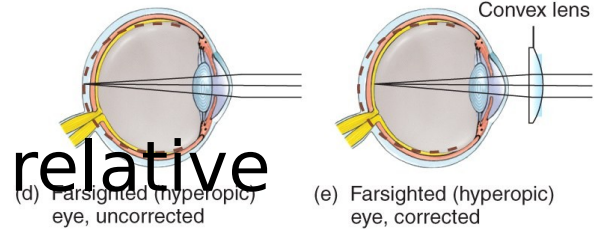


(a) Normal (emmetropic) eye



(b) Nearsighted (myopic) eye, uncorrected

(c) Nearsighted (myopic) eye, corrected



(d) Farsighted (hyperopic) eye, uncorrected

(e) Farsighted (hyperopic) eye, corrected

- **HYPEROPIA/HYPERMETROPHIA**

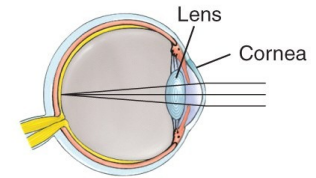
- the eyeball length is short relative to the focusing power of the cornea and lens, or the lens is thinner than normal

- **RESULT:** an image converges behind the retina

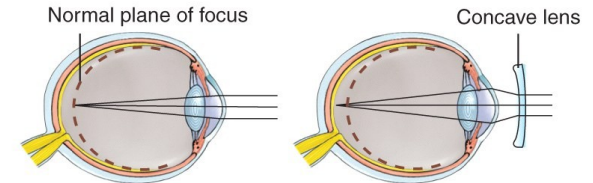
- Hyperopic individuals can see distant

IMAGE FORMATION

- REFRACTION ABNORMALITIES
(SIZE OF THE EYEBALL)

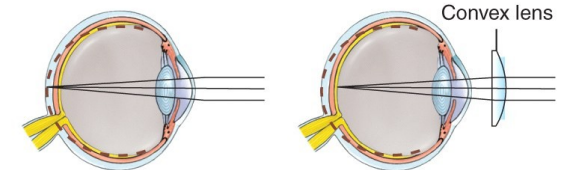


(a) Normal (emmetropic) eye



(b) Nearsighted (myopic) eye, uncorrected

(c) Nearsighted (myopic) eye, corrected



(d) Farsighted (hyperopic) eye, uncorrected

(e) Farsighted (hyperopic) eye, corrected

- ASTIGMATISM

- either the cornea or the lens has an irregular curvature.
- RESULT: parts of the image are out of focus, and thus vision is blurred or distorted.

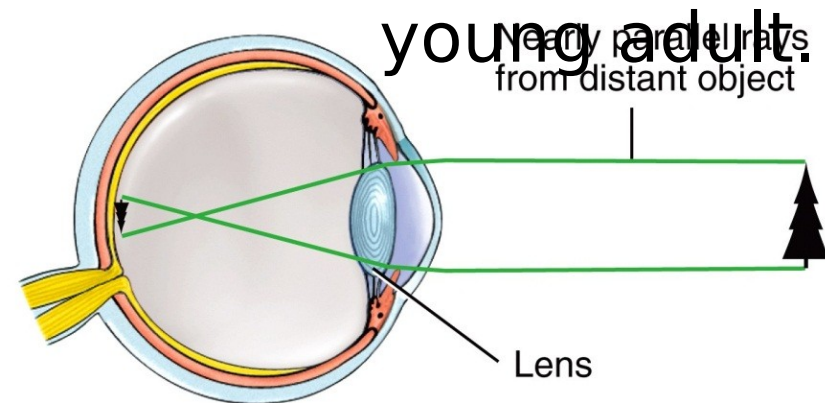
IMAGE FORMATION

2. **ACCOMMODATION**, the change in shape of the lens by increasing the curvature of the lens for near vision.

- **NEAR POINT OF VISION**

- the minimum distance from the eye that an object can be clearly focused with maximum accommodation.
- the distance is about 10 cm (4 in.) in a

young adult.



Viewing distant object

IMAGE FORMATION

2. ACCOMODATION

- when a person is viewing distant objects, the ciliary muscle of the ciliary body is relaxed and the lens is flatter because it is stretched in all directions by taut zonular fibers
- when you view a close object, the ciliary muscle contracts, which pulls the ciliary process and choroid forward toward the lens

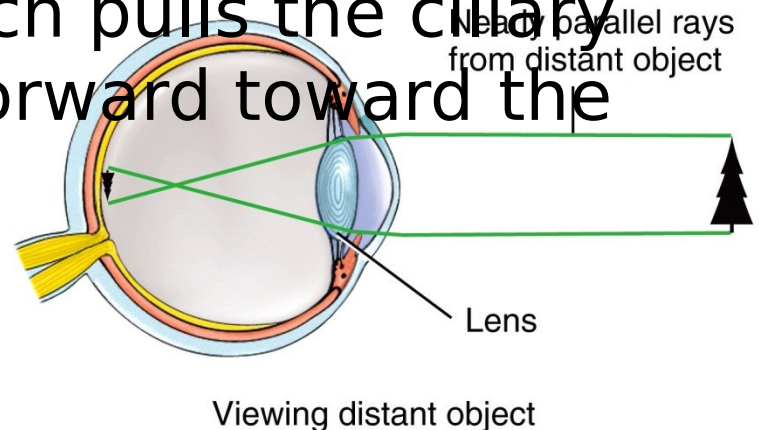
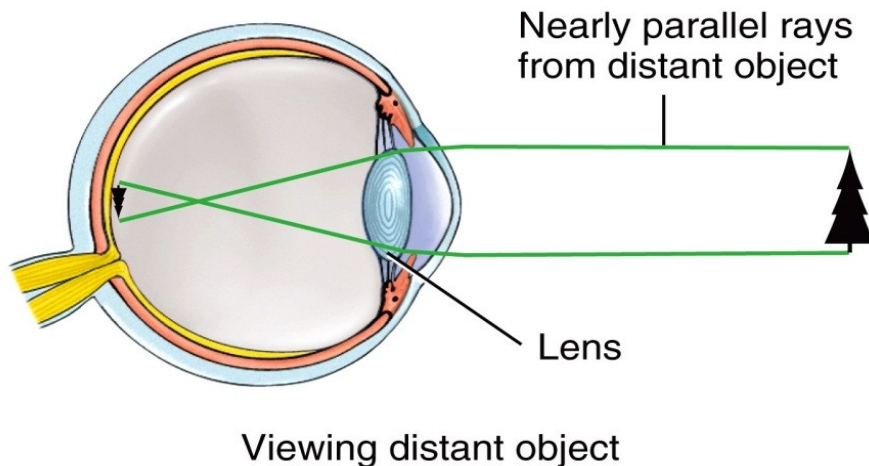


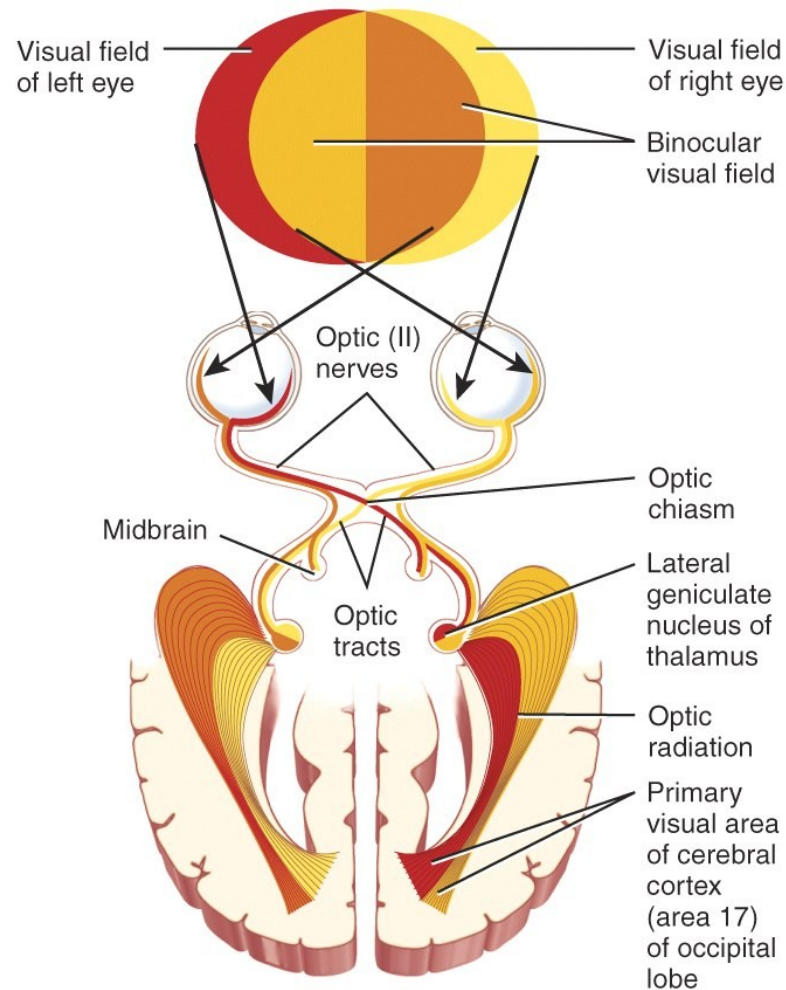
IMAGE FORMATION

3. CONSTRICTION or narrowing of the pupil

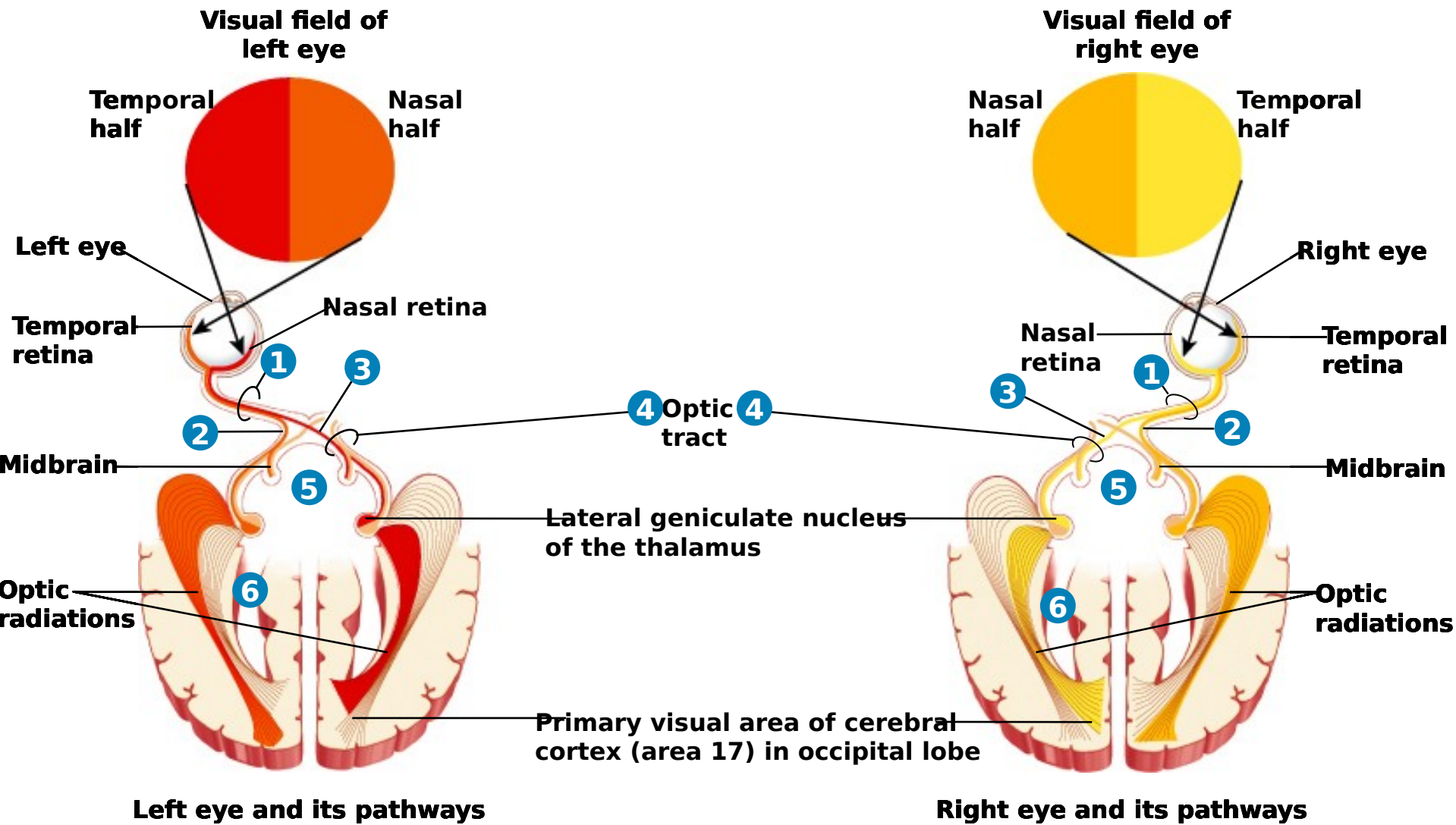
- occurs simultaneously with accommodation and prevents light rays from entering the eye through the periphery of the lens



VISUAL PATHWAY

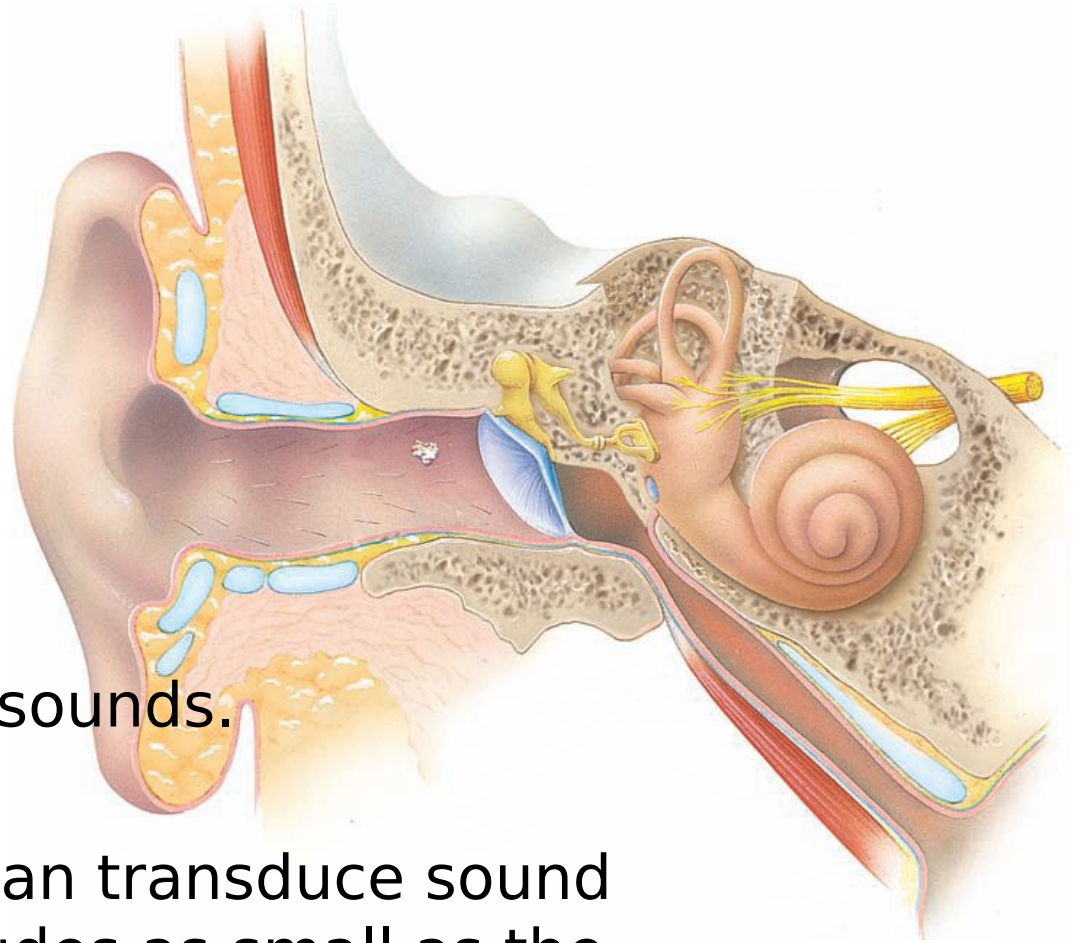


(b) Superior view of transverse section through eyeballs and brain



HEARING AND EQUILIBRIUM

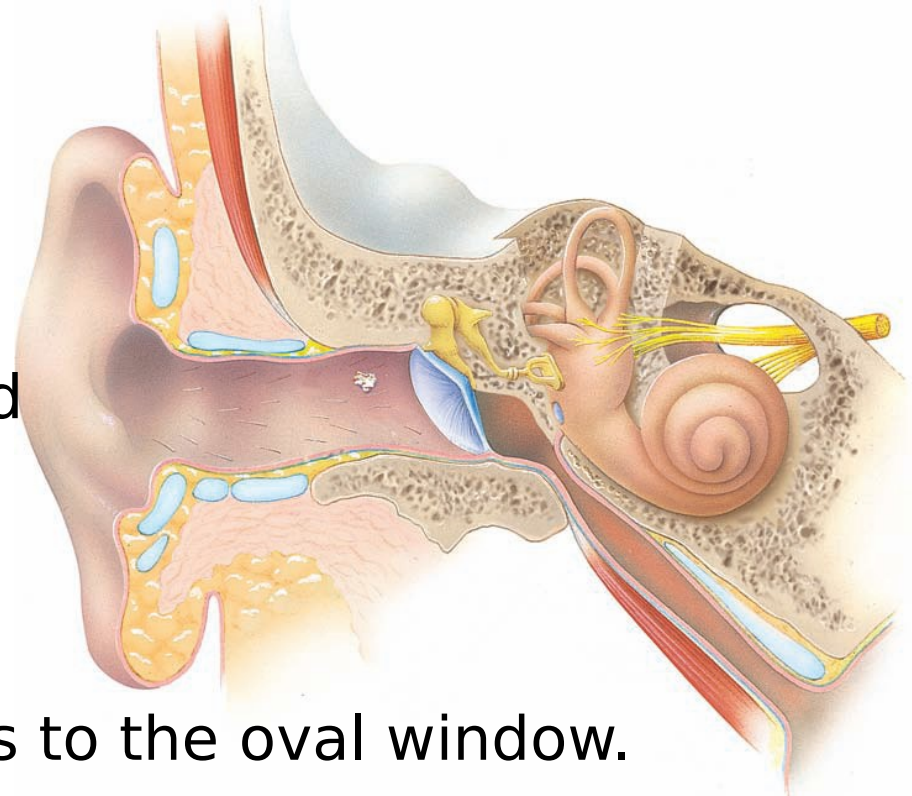
HEARING



- the ability to perceive sounds.
- its sensory receptors can transduce sound vibrations with amplitudes as small as the diameter of an atom of gold (0.3 nm) into electrical signals 1000 times faster than photoreceptors can respond to light.

ANATOMY OF THE EAR

- **EXTERNAL EAR**
 - collects sound waves and channels them inward.
- **MIDDLE EAR**
 - conveys sound vibrations to the oval window.
- **INTERNAL EAR**
 - houses the receptors for hearing and equilibrium.



ANATOMY OF THE EAR: EXTERNAL EAR

- AURICLE/ PINNA

- a flap of elastic cartilage shaped like the flared end of a trumpet and covered by skin.

- HELIX

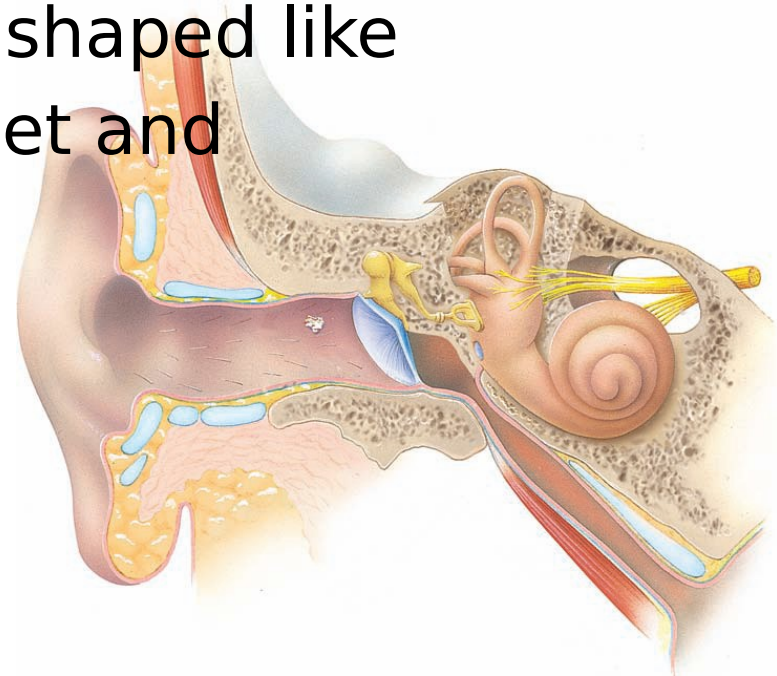
- the rim of the auricle

- LOBULE

- the inferior portion

- EXTERNAL AUDITORY CANAL

- a curved tube about 2.5 cm (1 in.) long that lies in the temporal bone and leads to the eardrum.



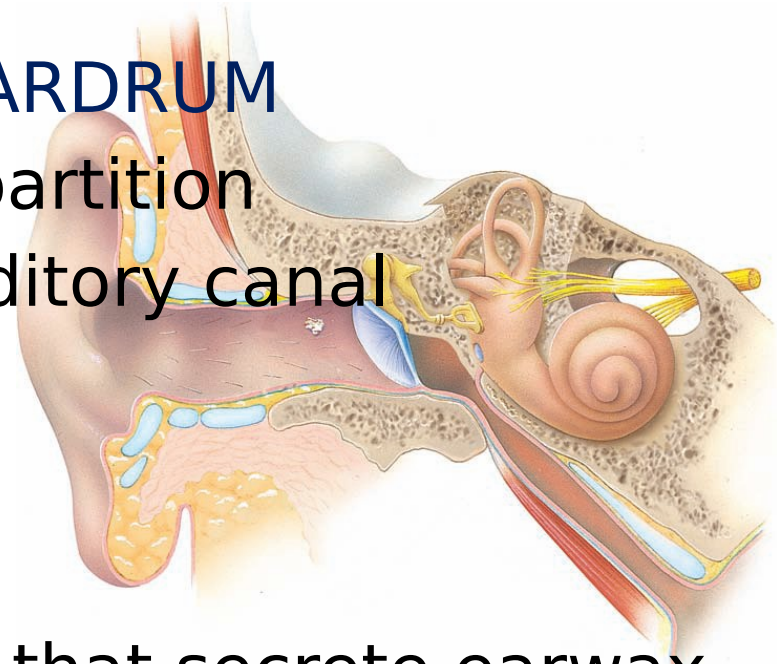
ANATOMY OF THE EAR: EXTERNAL EAR

- **TYMPANIC MEMBRANE or EARDRUM**

- a thin, semitransparent partition between the external auditory canal and middle ear.

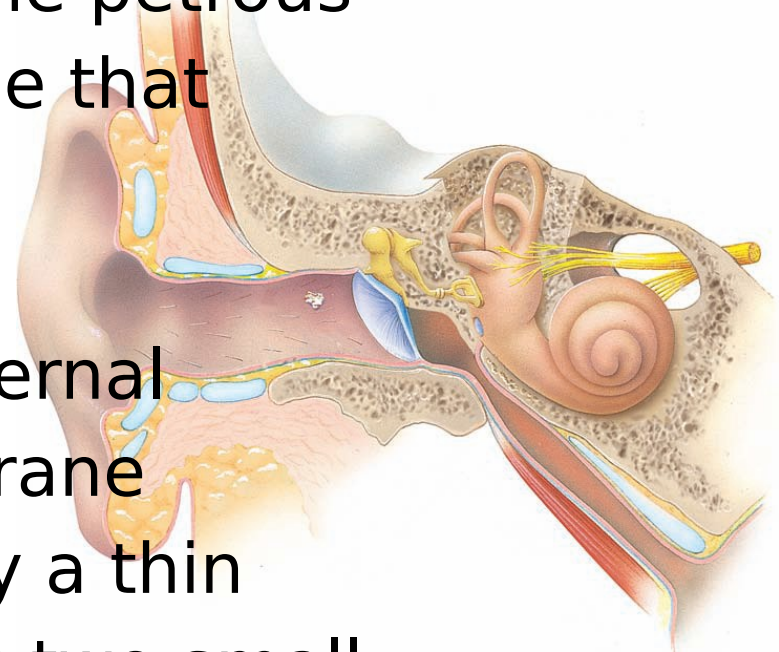
- **CERUMINOUS GLANDS**

- specialized sweat glands that secrete earwax or cerumen



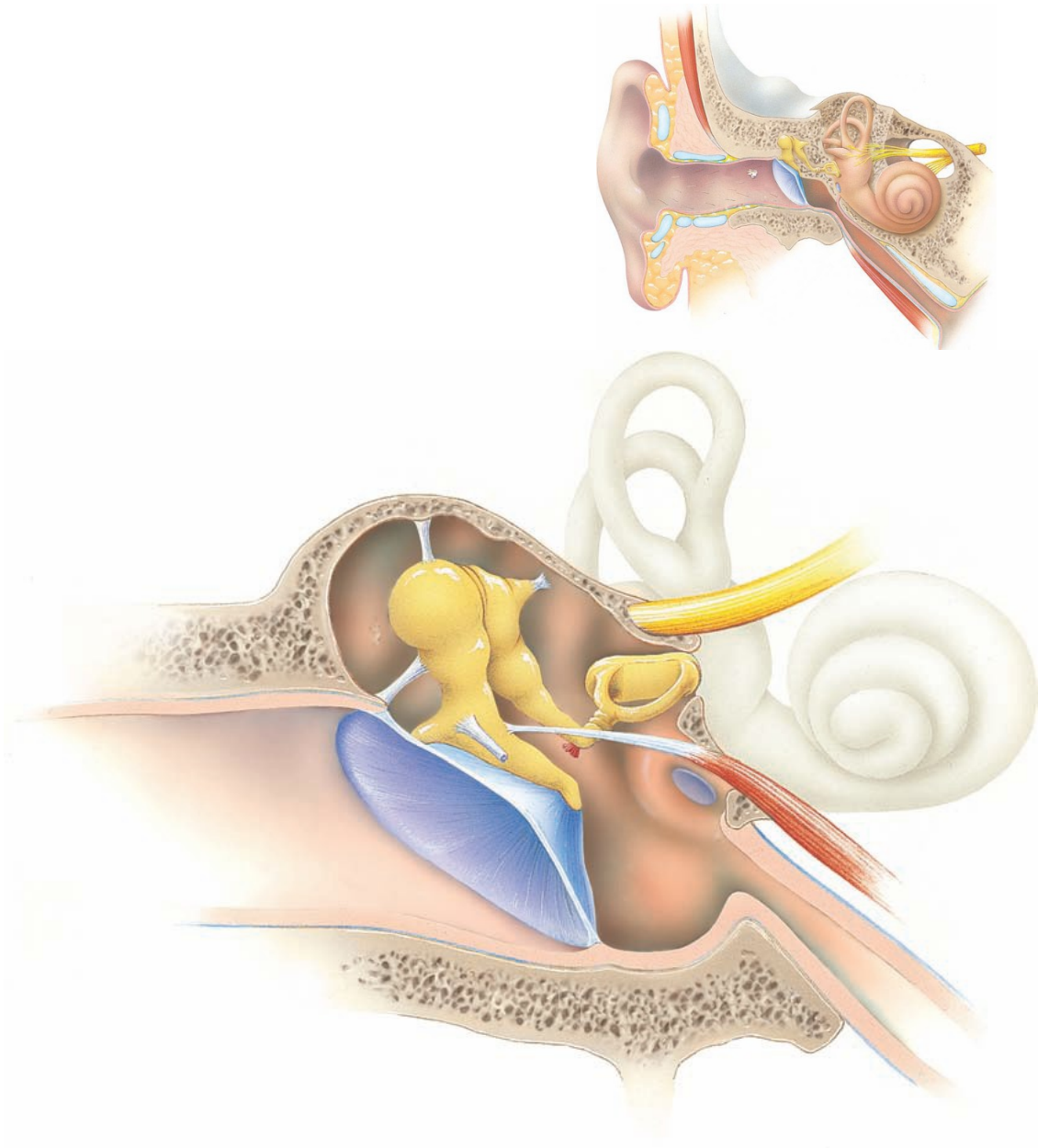
ANATOMY OF THE EAR: MIDDLE EAR

- a small, air-filled cavity in the petrous portion of the temporal bone that is lined by epithelium
- It is separated from the external ear by the tympanic membrane and from the internal ear by a thin bony partition that contains two small membrane-covered openings: the oval window and the round window



ANATOMY OF THE EAR: MIDDLE EAR

- AUDITORY OSSICLES
 - MALLEUS
 - INCUS
 - STAPES

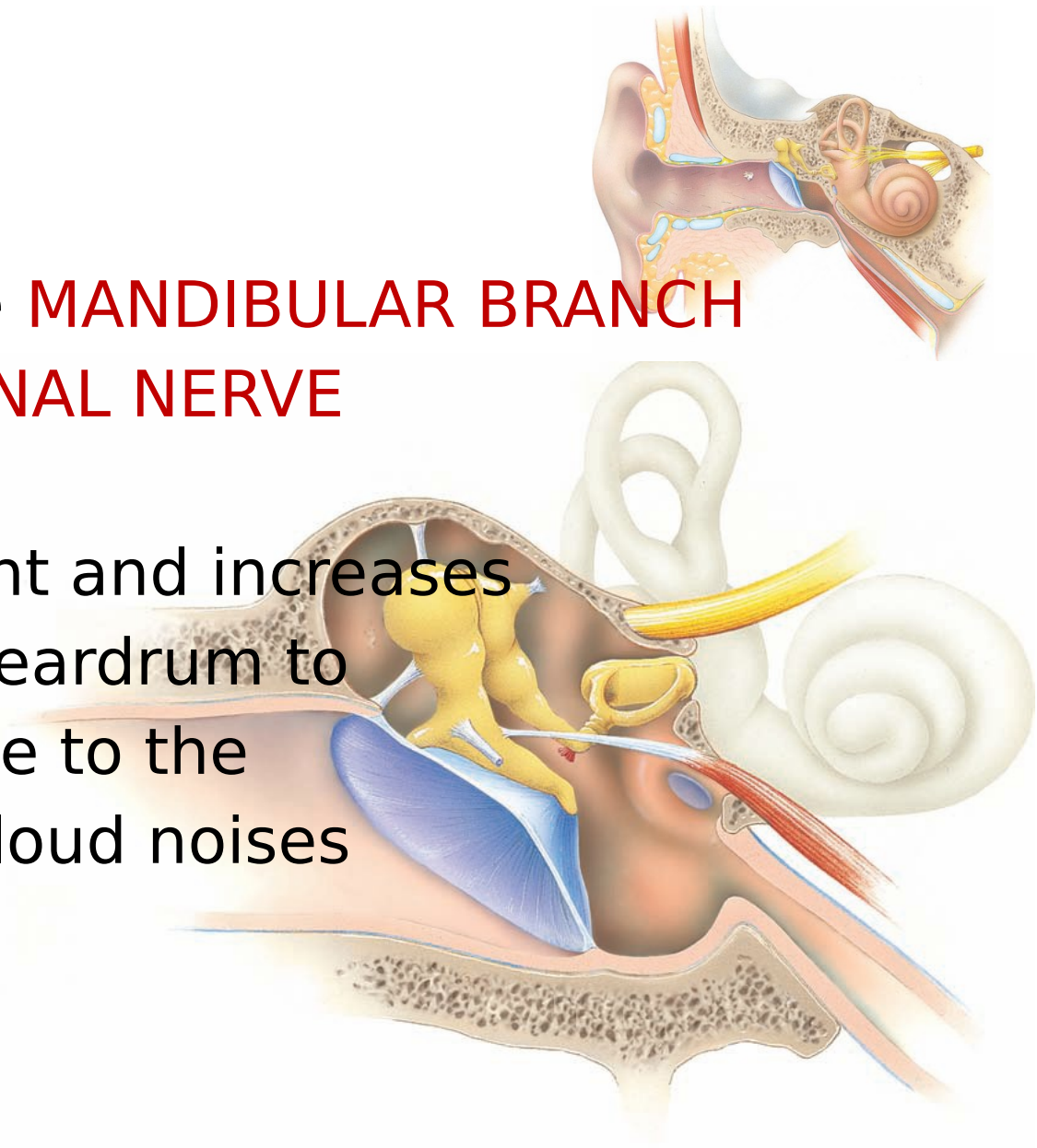


ANATOMY OF THE EAR: MIDDLE EAR

- TENSOR TYMPANI

- supplied by the **MANDIBULAR BRANCH** of the **TRIGEMINAL NERVE**

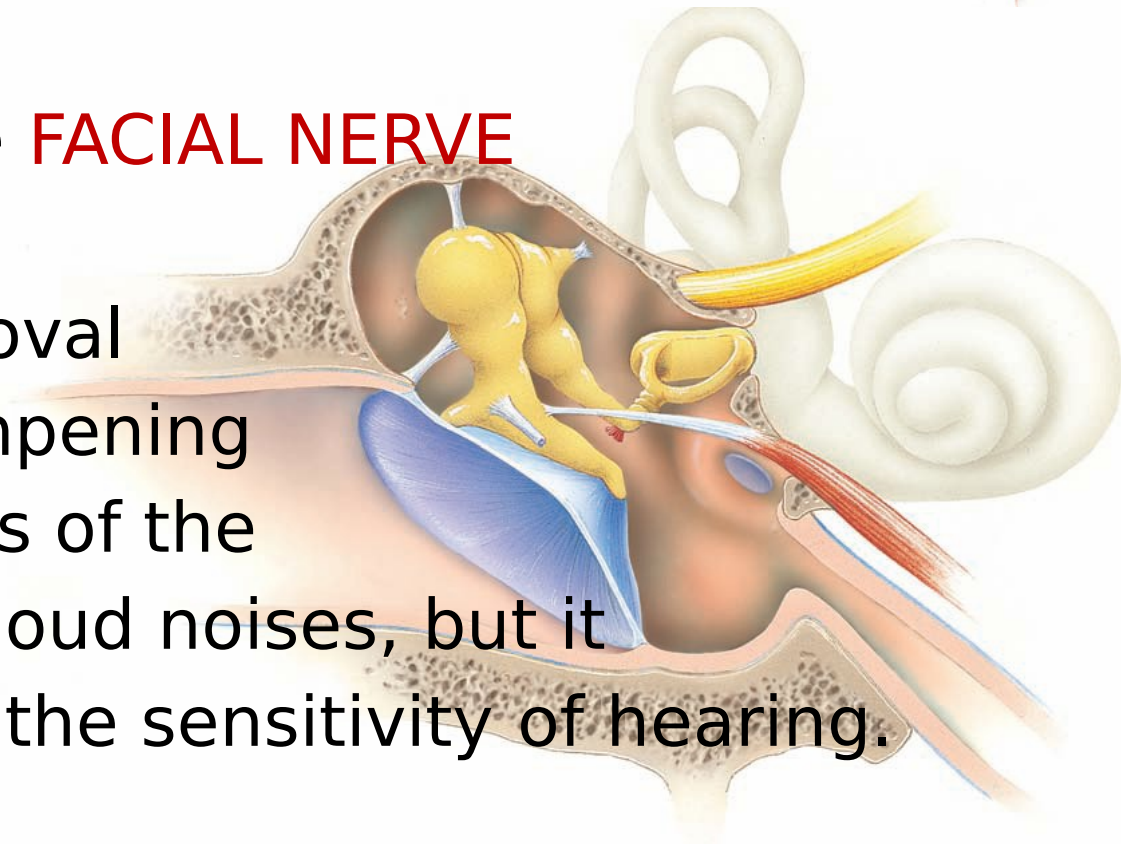
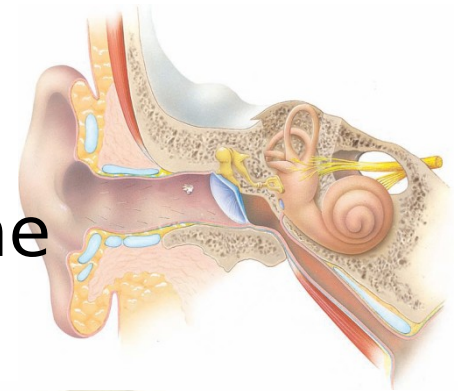
- limits movement and increases tension on the eardrum to prevent damage to the inner ear from loud noises



ANATOMY OF THE EAR: MIDDLE EAR

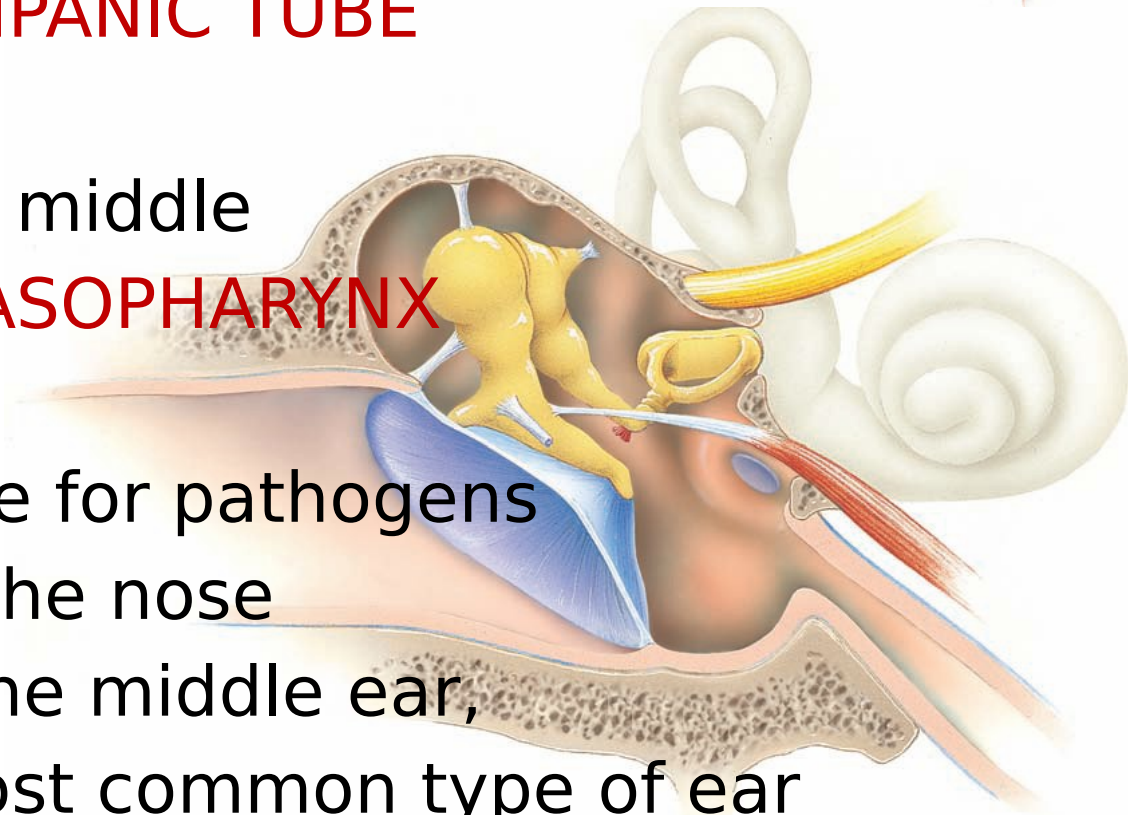
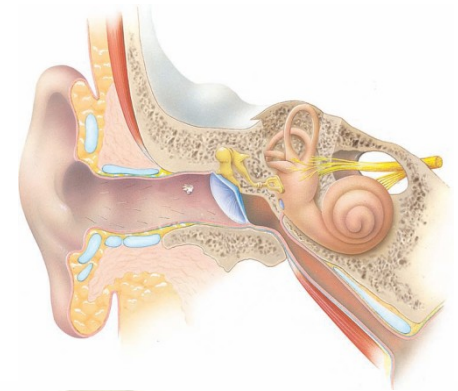
- STAPEDIUS

- the smallest skeletal muscle in the human body
- supplied by the FACIAL NERVE
- it protects the oval window by dampening large vibrations of the stapes due to loud noises, but it also decreases the sensitivity of hearing.



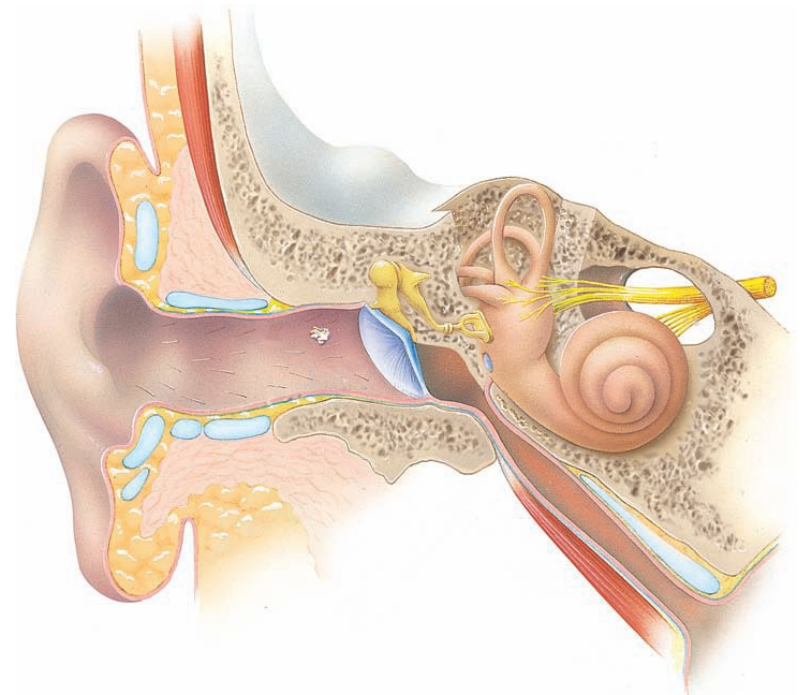
ANATOMY OF THE EAR: MIDDLE EAR

- AUDITORY TUBE
 - EUSTACHIAN TUBE
 - PHARYNGOTYMPANIC TUBE
- It connects the middle ear with the **NASOPHARYNX**
- It is also a route for pathogens to travel from the nose and throat to the middle ear, causing the most common type of ear infection.



ANATOMY OF THE EAR: INTERNAL (INNER) EAR

- LABYRINTH
 - It consists of complicated series of canals
- BONY LABYRINTH
- MEMBRANOUS LABYRINTH



ANATOMY OF THE EAR: INTERNAL (INNER) EAR

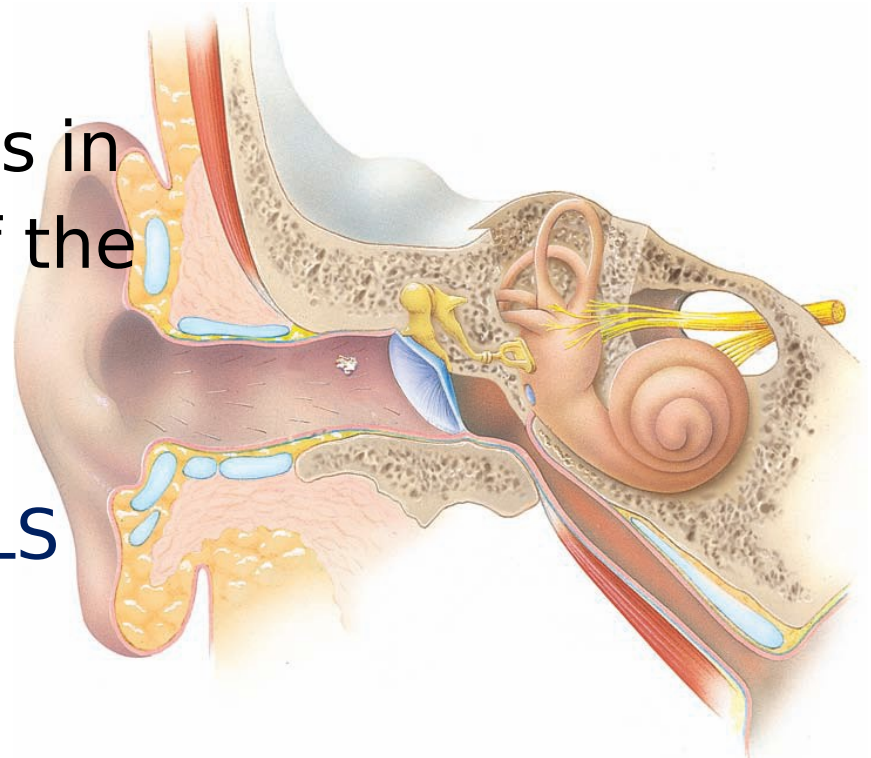
- BONY LABYRINTH

- It is a series of cavities in the petrous portion of the temporal bone

- SEMICIRCULAR CANALS

- VESTIBULE

- COCHLEA



ANATOMY OF THE EAR: INTERNAL (INNER) EAR

- BONY LABYRINTH

- PERILYMPH

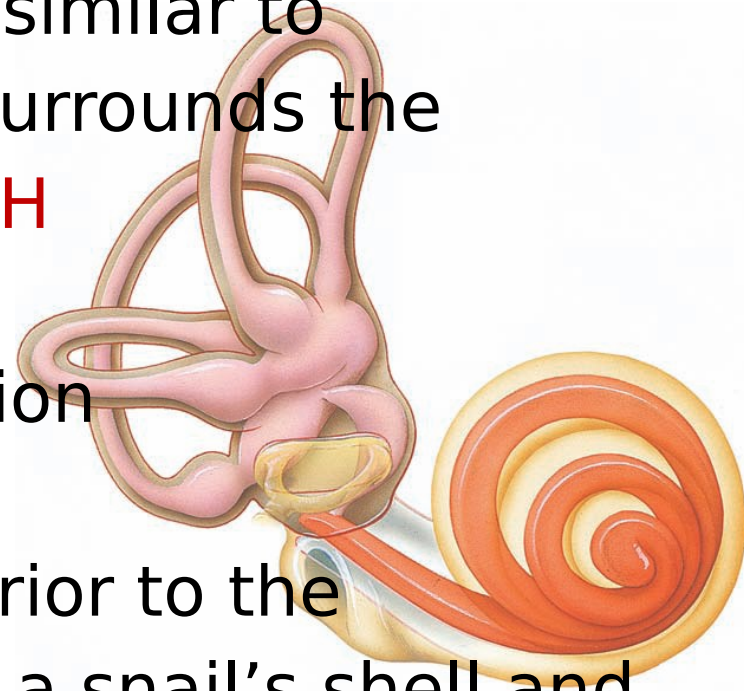
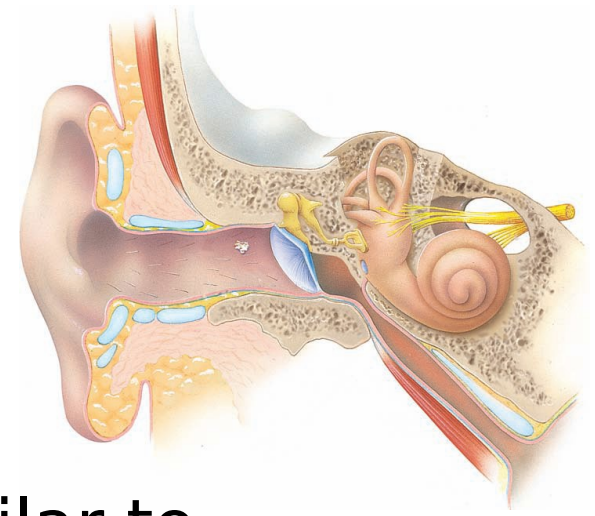
- fluid which is chemically similar to cerebrospinal fluid that surrounds the MEMBRANOUS LABYRINTH

- VESTIBULE

- It is the oval central portion

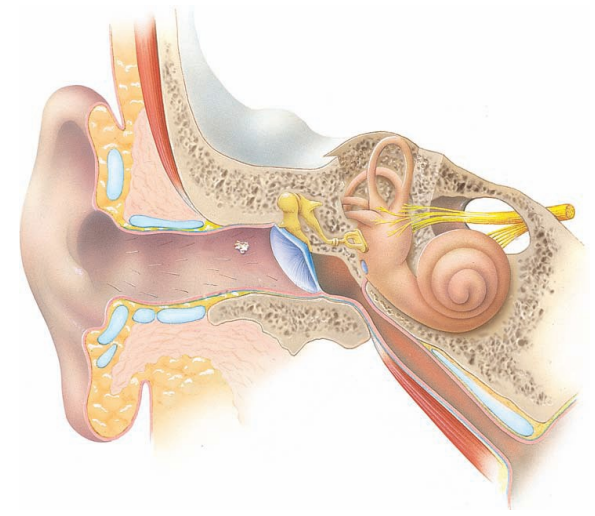
- COCHLEA

- A bony spiral canal, anterior to the vestibule that resembles a snail's shell and makes almost three turns around a central bony core (MODIOLUS)



ANATOMY OF THE EAR: INTERNAL (INNER) EAR

- BONY LABYRINTH

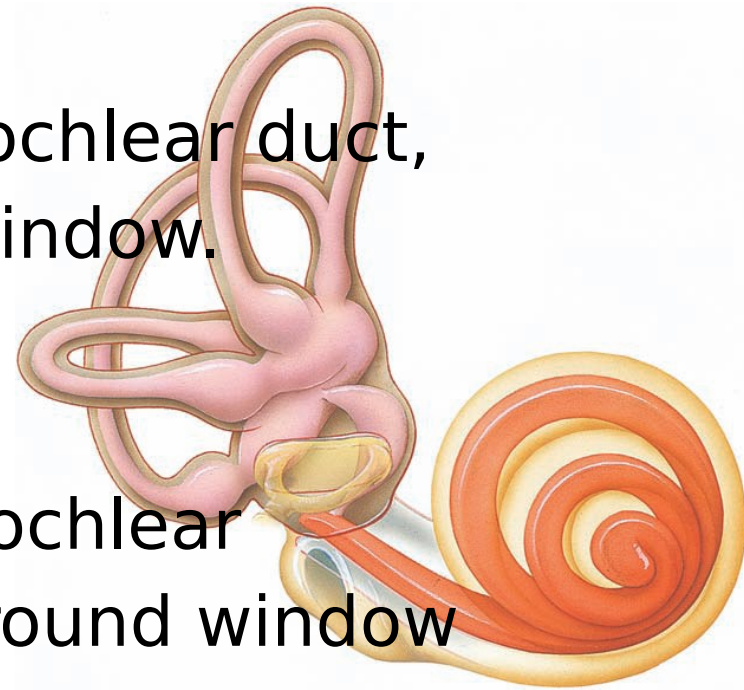


- SCALA VESTIBULI

- the channel above the cochlear duct, which ends at the oval window.

- SCALA TYMPANI

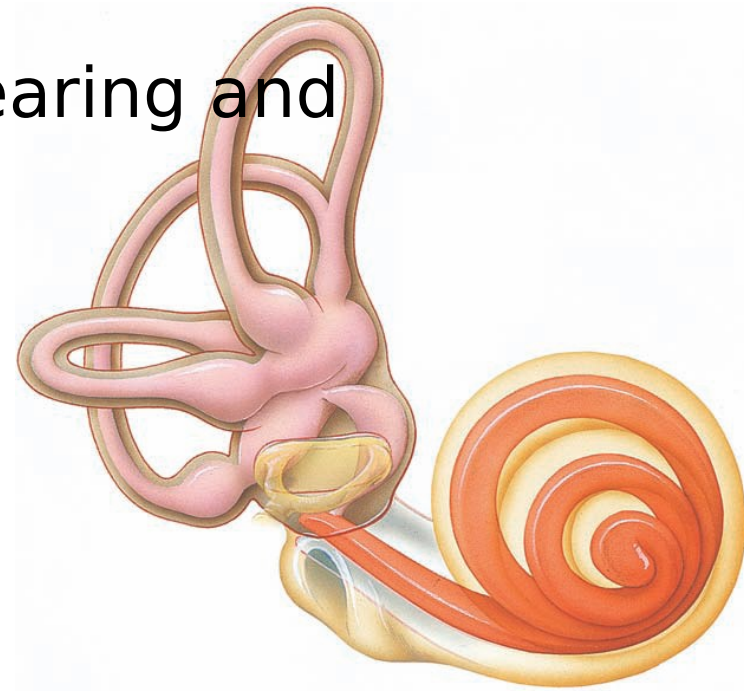
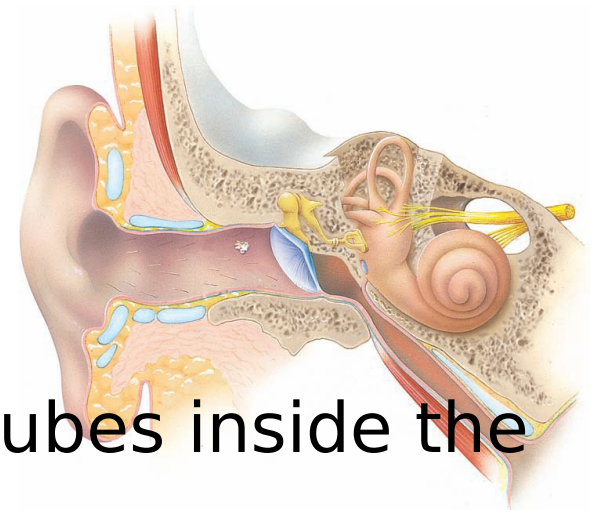
- The channel below the cochlear duct, which ends at the round window



ANATOMY OF THE EAR: INTERNAL (INNER) EAR

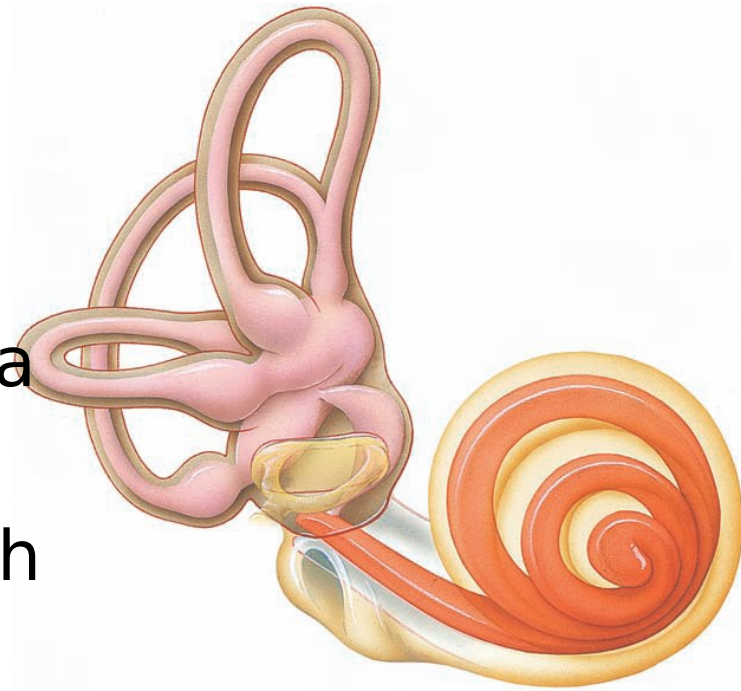
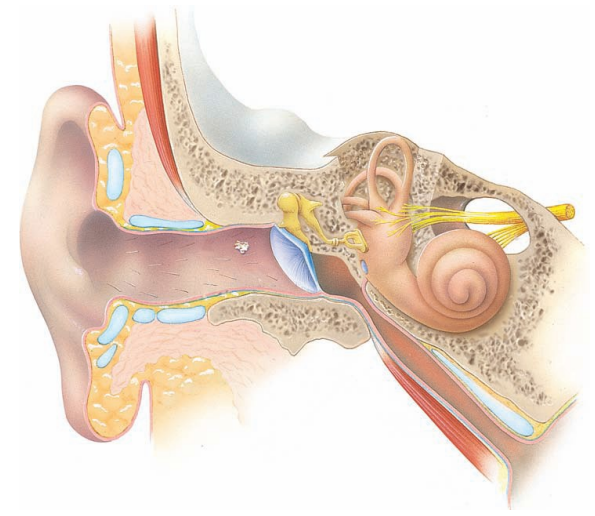
- MEMBRANOUS LABYRINTH

- a series of epithelial sacs and tubes inside the bony labyrinth
- houses the receptors for hearing and equilibrium
- UTRICLE
- SACCULE
- SEMICIRCULAR CANALS

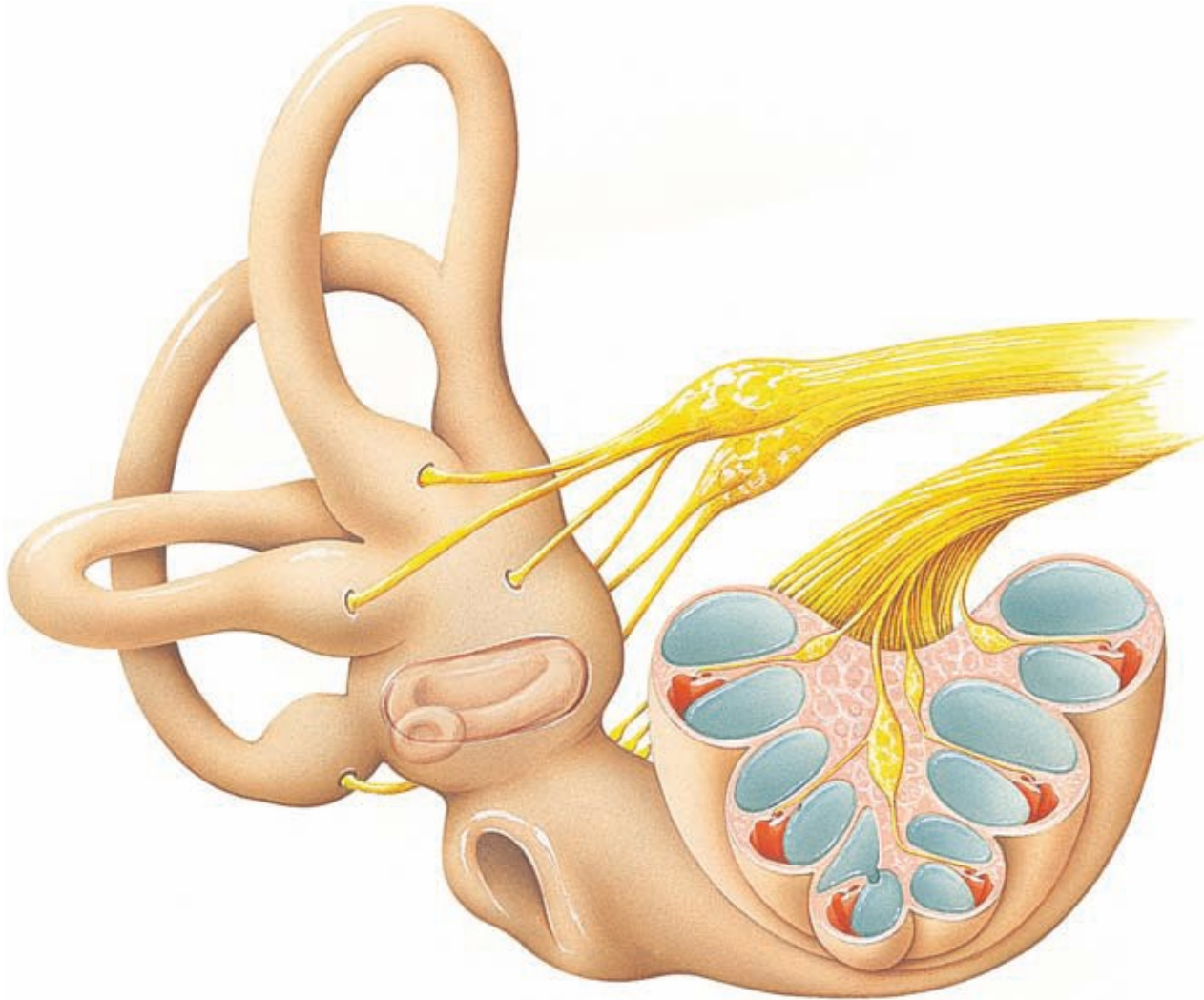


ANATOMY OF THE EAR: INTERNAL (INNER) EAR

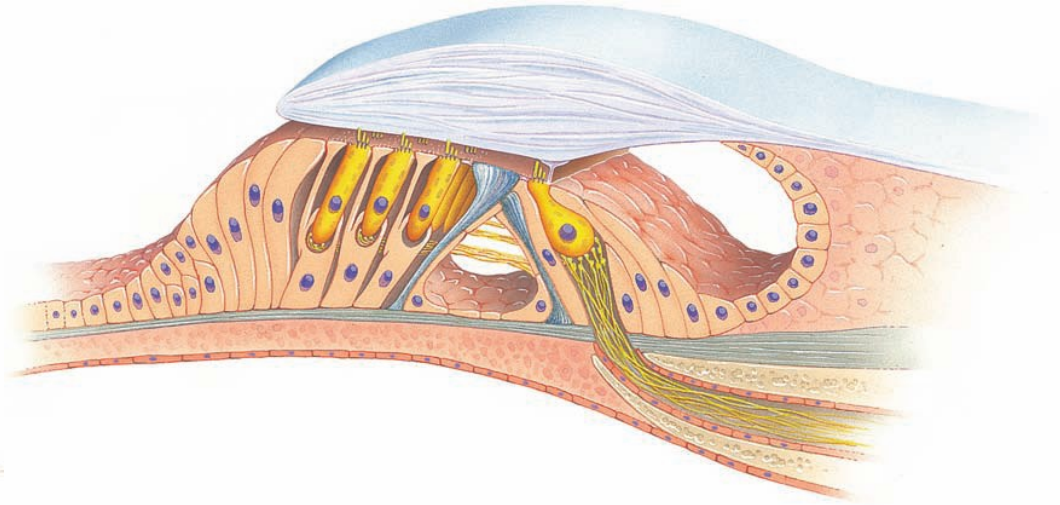
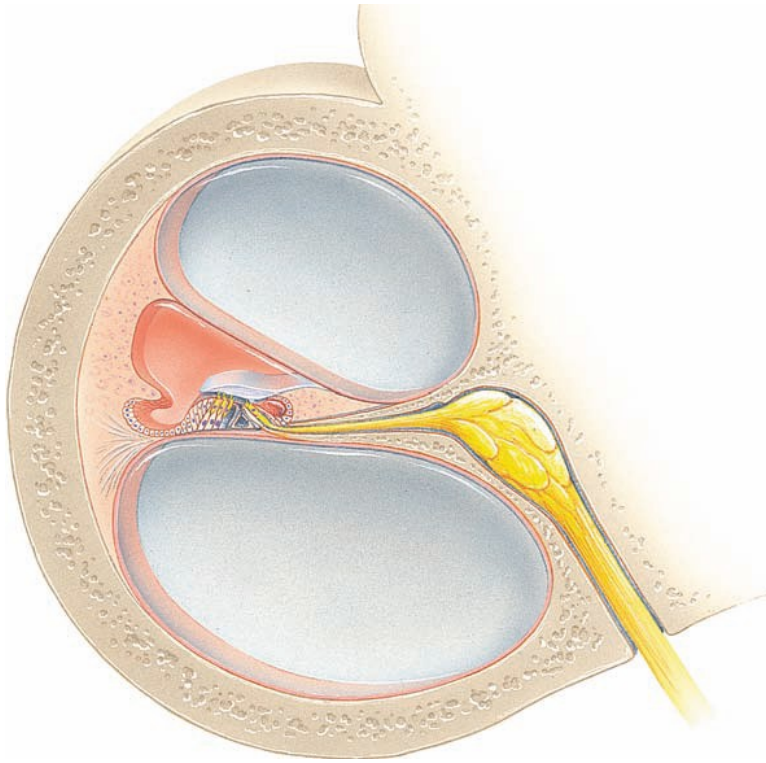
- MEMBRANOUS LABYRINTH
 - COCHLEAR DUCT
 - a continuation of the membranous labyrinth into the cochlea
 - it is filled with endolymph



Components of Vestibulocochlear nerve (cranial nerve VIII)



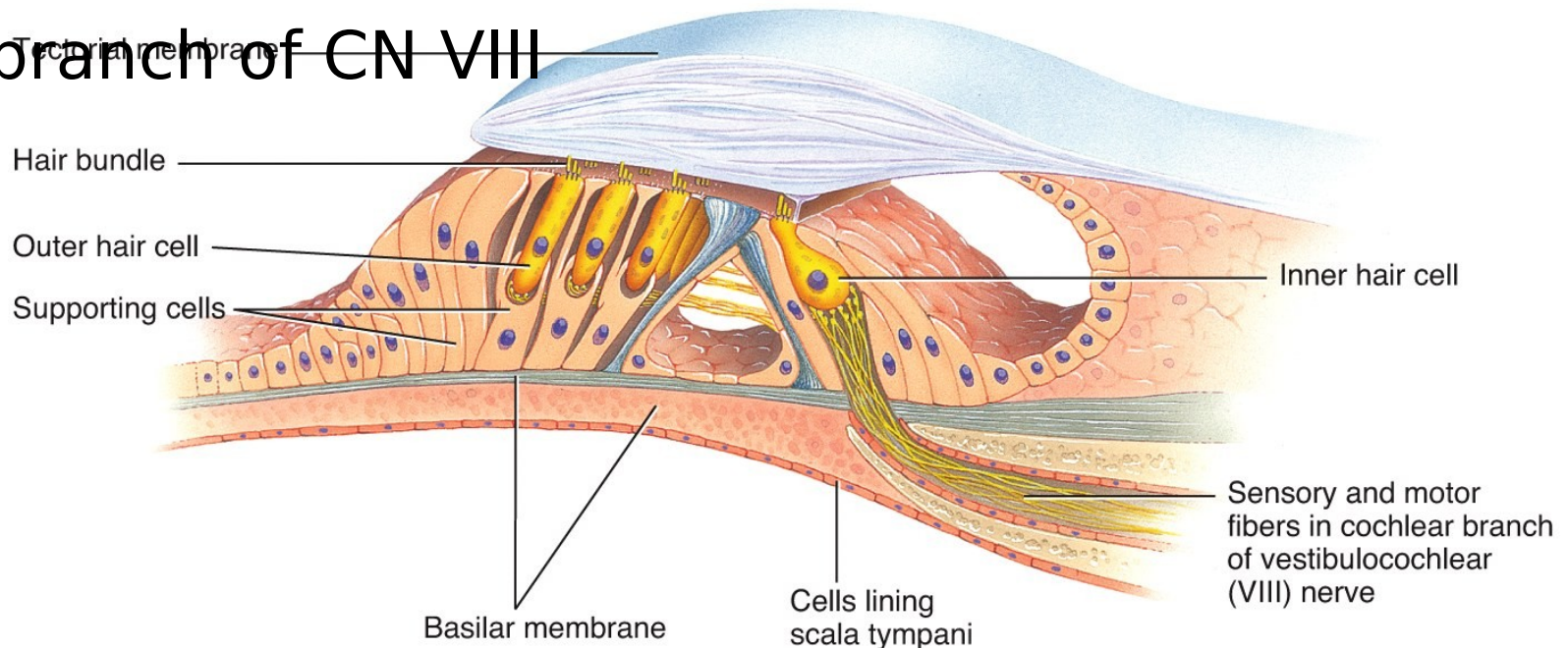
SPIRAL ORGAN (ORGAN OF CORTI)



The Inner Ear

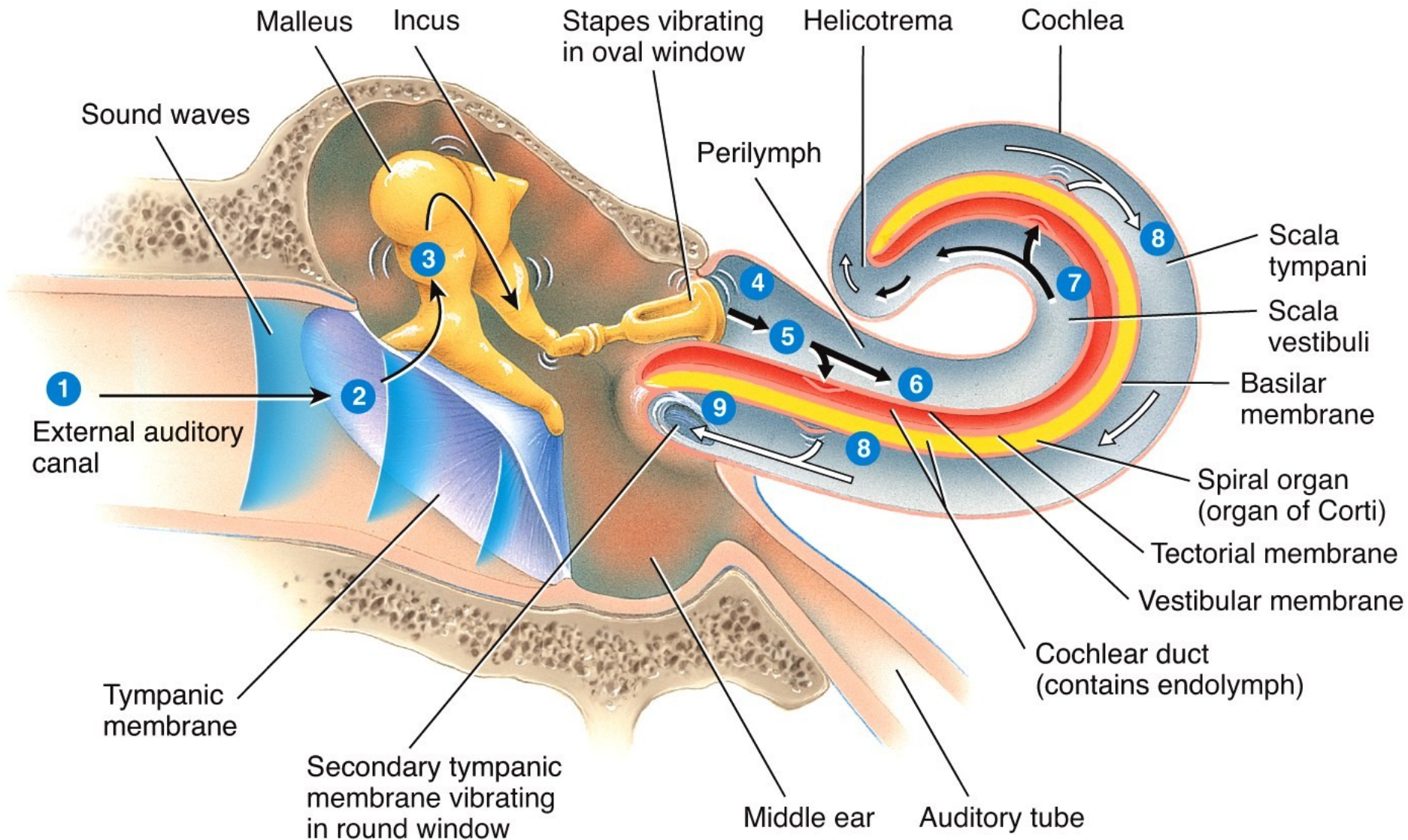
- Movements of the hair cells in contact with the tectorial membrane **transduce mechanical vibrations** into electrical signals which generate nerve impulses along the cochlear

branch of CN VIII



(d) Enlargement of spiral organ (organ of Corti)

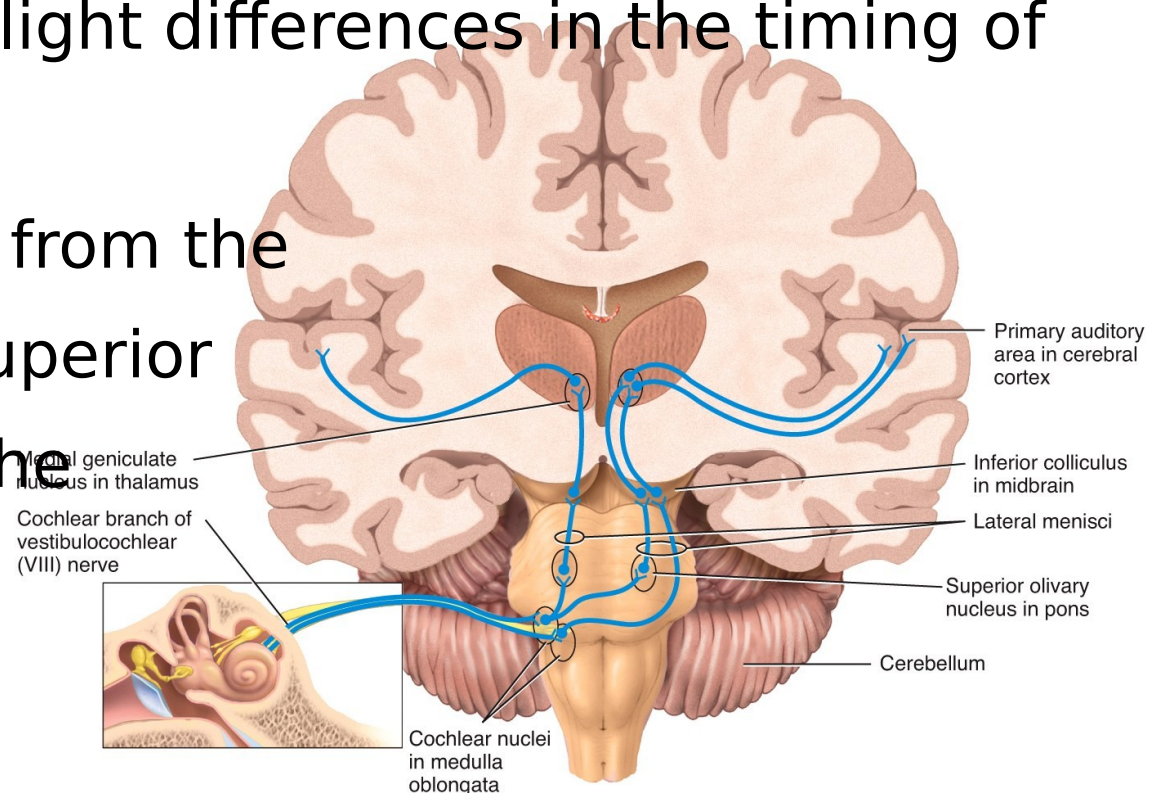
The Auditory Pathway



The Auditory Pathway

- The nerve impulses follow CN VIII en route to the medulla, pons, midbrain, and thalamus, and finally to the primary auditory cortex in the temporal lobe. Slight differences in the timing of nerve

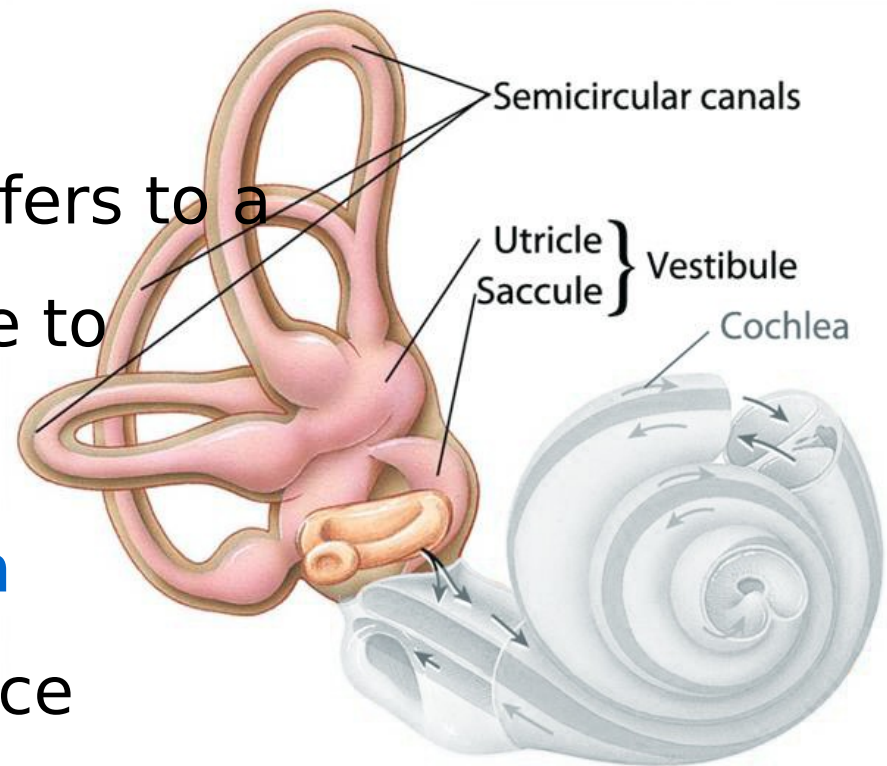
impulses arriving from the two ears at the superior olivary nuclei in the pons allow us to locate the source of a sound



Equilibrium

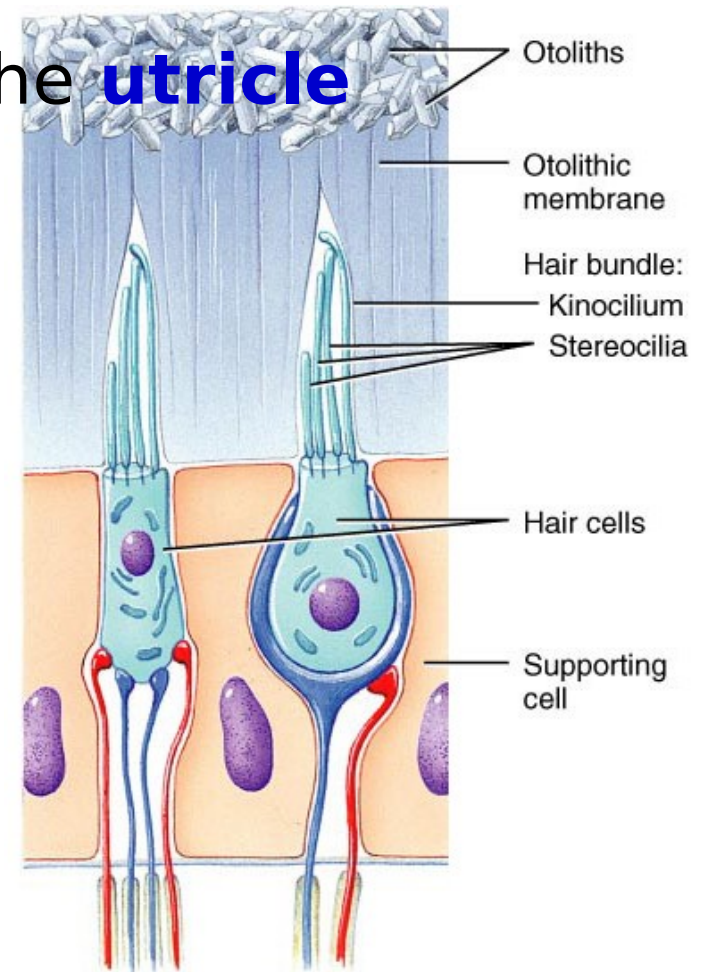
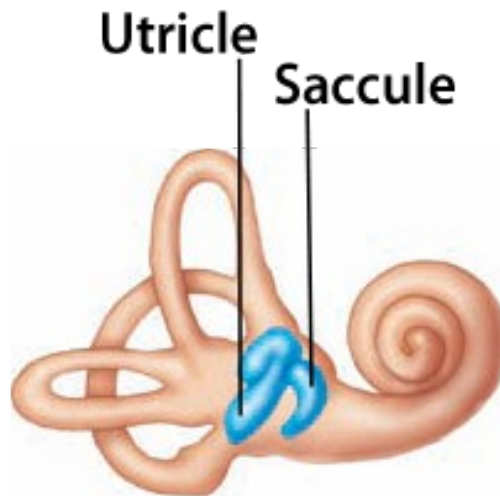
- Equilibrium is another function of the inner ear - controlled by the **vestibular apparatus** (the saccule and utricle of the vestibule, and the 3 semicircular canals)

- **Static equilibrium** refers to a state of balance relative to the force of gravity
- **Dynamic equilibrium** involves the maintenance of balance during sudden movements



Static Equilibrium

- Static equilibrium is controlled by the **sensory hairs** within the macula of the **utricle** and **saccul**

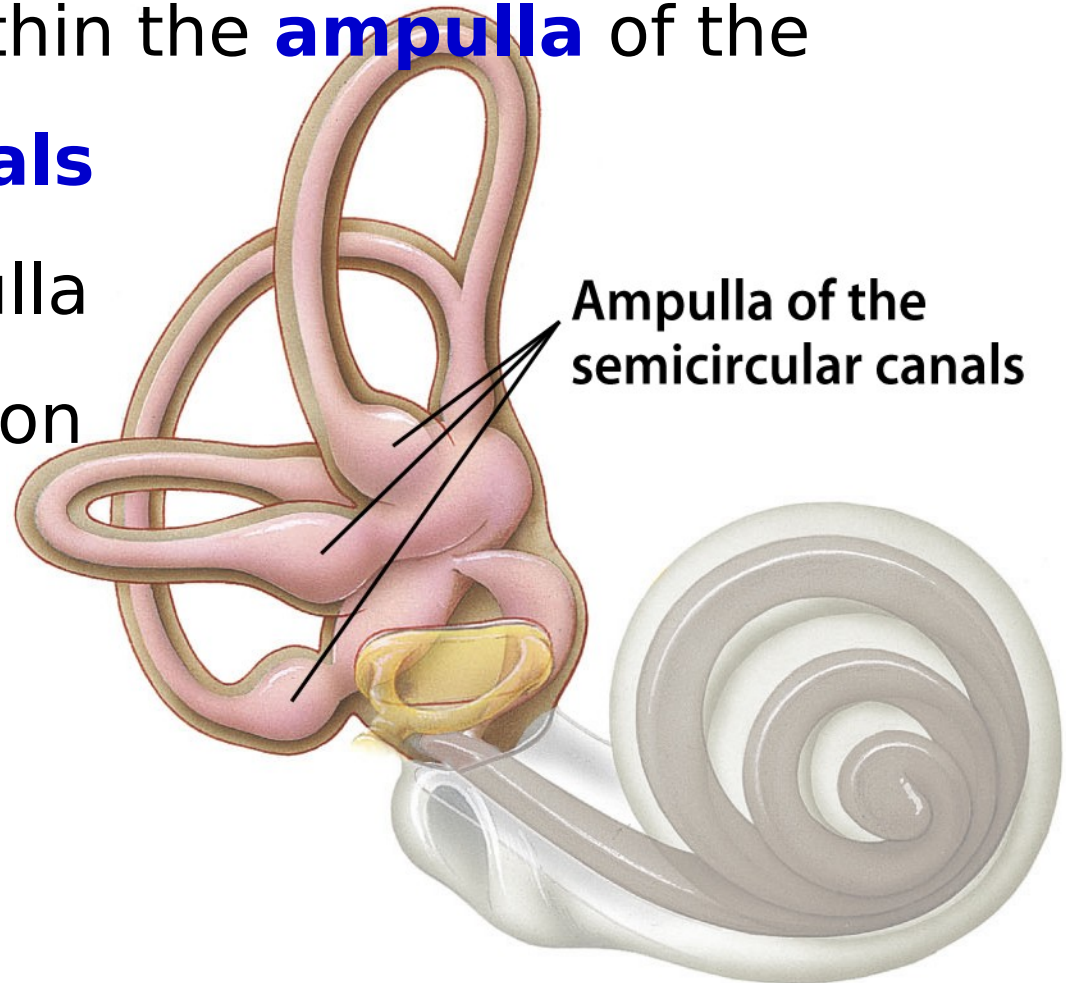


Details of two hair cells

Dynamic Equilibrium

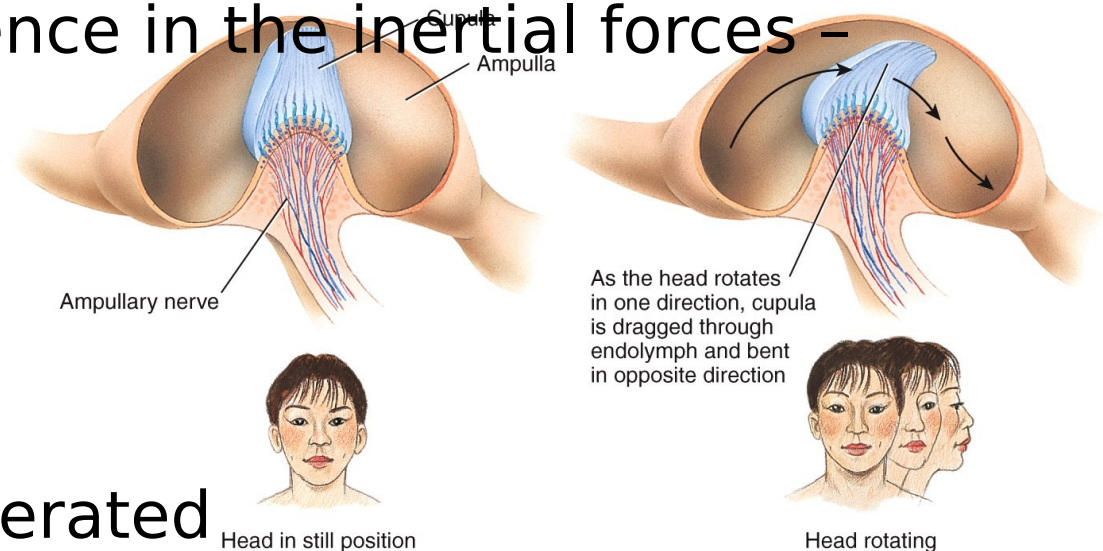
- Dynamic equilibrium is controlled by the **sensory hairs** within the **ampulla** of the **semicircular canals**

-Within each ampulla is a small elevation called the **crista**



Dynamic Equilibrium

- Each crista contains hair cells and supporting cells covered by gelatinous material called the **cupula**
- With movement, the endolymph within the ampulla lags behind the moving cupula, causing a difference in the inertial forces – the hair bundle of the cupula bends and nerve impulses are generated



Equilibrium Pathway

- Once generated, nerve impulse travel up the vestibular branch of CN VIII. Most of these axons synapse in the major integrating centers for equilibrium, in the medulla and pons, which also receive input from the eyes and proprioceptors
 - Ascending neurons continue to **primary auditory area** in the **parietal lobe** to provide us with conscious awareness of the position and movements of the head and limbs